STUDY OF THE HEALTH EFFECTS OF LOW-LEVEL EXPOSURE TO ENVIRONMENTAL RADIATION CONTAMINATION IN PORT HOPE, ONTARIO

EXECUTIVE SUMMARY

A Committee was established in 1980 by the Minister of Health, Ontario, and the Minister of Health and Welfare Canada, to design and oversee the conduct of a study of Port Hope residents.

The Committee members were represented by the Medical Officer of Health, Port Hope, Health and Welfare Canada, and the Ontario Ministry of Health.

A contract was awarded to Queen's University, Department of Epidemiology, to conduct a case-control study of lung cancer in Port Hope residents. This study was conducted to evaluate the relative importance of domestic radiation exposure due to radioactive contamination of homes from industrial sources in Port Hope.

Eldorado Nuclear Limited (ENL) has been situated in Port Hope since 1932 in order to process radioactive ores from various sources in Canada. Radioactive residues and building materials from the plant were used as landfill variously throughout the town. Approximately 150 homes were identified as radon contaminated homes.

Lung cancer cases and controls or their relatives were interviewed. This information, combined with data from previous radiation surveys, provided information of individual radiation exposure and other risk factors such as smoking. Workers from ENL were excluded because of possible workplace exposure. Twenty-seven cases who met the study criteria were matched by forty-nine controls.

Statistical analyses showed a very strong association between lung cancer and smoking. Over 90% of the lung cancer cases were attributable to smoking. It has been well established from numerous previous studies that both smoking and alpha radiation increase lung cancer risk. It has been generally assumed that, as to radiation effects, there is no level that is completely risk free. Because of the low number of cases and the low level of exposure, this relationship could not be confirmed statistically in this study.

The analyses did not show a statistically significant increased risk of lung cancer from elevated alpha radiation levels in these homes.

It should be recognized that there were only four cases of lung cancer in contaminated homes, and each was a cigarette smoker.

Mrs. Jean Sattar
Media Relations
Health Protection Branch
Health Protection Branch Building
Tunney's Pasture
Ottawa, Ontario
K1A 0L2

Anne-Marie Montgomery
Health Promotion and Information Branch
80 Grosvenor Street
9th Floor
Hepburn Block
Toronto, Ontario
M7A 2C4
(416) 965-5167

STUDY OF THE HEALTH EFFECTS OF LOW-LEVEL EXPOSURE TO ENVIRONMENTAL RADIATION CONTAMINATION IN PORT HOPE, ONTARIO

REPORT
JUNE 4, 1984

TABLE OF CONTENTS

INVESTIGATORS i
ACKNOWLEDGEMENTS ii
GLOSSARY OF TERMS iii

1. STUDY SETTING
   1.1 Background 1
   1.2 Investigation of Contaminated Sites in Port Hope 2
2. FEASIBILITY STUDY 6
3. TERMS OF REFERENCE 8
4. METHOD
   4.1 Start-up Activities 11
   4.2 Questionnaire Development and Testing 13
   4.3 Identification of Cases 15
   4.4 Interviewing Cases 18
   4.5 Tracing of Cases 19
   4.6 Selection of Controls 20
   4.7 Identification of Controls 20
   4.8 Verification, Tracing and Interviewing of Controls 21
5. DATA COLLECTION
   5.1 Personal Information 23
   5.2 Medical Records 23
   5.3 Data Coding and Review 24
   5.4 Estimates of Radiation Exposure 25
   5.5 Corrected Radiation Exposure 26
6. DATA ANALYSIS 29
7. RESULTS 32
   TABLES 1 - 12 AND FIGURES 1 - 5
8. DISCUSSION 34
9. CONCLUSIONS 39

TABLE OF CONTENTS (cont'd)

REFERENCES
APPENDIX 1 - Map
APPENDIX 2 - Information Sheet
APPENDIX 3 - Doctor's Letter
APPENDIX 4 - Interview Form
APPENDIX 5 - Interview Consent Form
APPENDIX 6 - Medical Records Release Consent Form
APPENDIX 7 - Medical Records Data Sheet
APPENDIX 8 - Data Summary Sheet
APPENDIX 9 - Coding Sheet
APPENDIX 10 - Senes Consultants Report

INVESTIGATORS

R. STEELE, M.D.	PRINCIPAL INVESTIGATOR
R.E.M. LEES, M.D.	PRINCIPAL INVESTIGATOR
J. HATCHER ROBERTS M.Sc.	CO-INVESTIGATOR/PROJECT DIRECTOR

NORMAN HELFAND, B.Sc. - DATA ANALYST

SHERRY ROBINSON, M.ED. - FIELD STAFF - INTERVIEWER, DATA COLLECTOR

MARTHA NOSAL B.A. - FIELD STAFF - RESEARCH ASSISTANT

A. WILLAN, Ph.D. - CONSULTANT STATISTICIAN

SENES CONSULTANTS LIMITED - ENGINEERING CONSULTANTS

D. CHAMBERS, Ph.D. and

G. CASE, P.ENG.

ASSISTANCE WITH THE DESIGN OF THE STUDY - PROVIDED BY T.O. SIU, D.Sc.

ACKNOWLEDGEMENTS

The Port Hope Health Study Team would like to thank the following people:

Drs. R. Spengler and N. Kreiger, of Ontario Cancer Treatment and Research Foundation for their expert assistance and advice in providing lists of cases and controls;

Dr. D.E. Mikel, Medical Officer of Health, Cobourg and Mrs. Minaker, Public Health Nurse, of the Haliburton, Kawartha, Pine Ridge District Health Unit;

Executive Directors and Medical Records Personnel of the following hospitals: Toronto General, Toronto Western, Sunnybrooke, Princess Margaret, Cobourg, Port Hope, Peterborough Civic, St. Joseph's Peterborough, Bowmanville and Oshawa General.

PORT HOPE PHYSICIANS: Dr. Routh, Dr. Mack, Dr. R. Tesluk and especially Dr. Kerins, Dr. Davies, Dr. Harrison and Dr. P. Hazell; COBOURG PHYSICIANS: Dr. Rose, Dr. Jones and Dr. Shaw, and The late Dr.Levy of PETERBOROUGH, for their co-operation.

Dr. Stewart Lott, Director, Kingston Cancer Clinic; Mr. Marshall Elliott, Executive Director, Haliburton, Kawartha, Pine Ridge District Health Council; Dr. John Abbott, Medical Advisor, Eldorado Nuclear Limited for providing employment exposure data; Mr. Heino Lillis, LLB, LLM, Executive Assistant to the Vice-Principal, Queen's University for his legal advice; Mr. Gary Russell, Townview Business Centre for providing accommodation for the study team office.

A special thanks to Barbara Gee, Linda Chinnery and Gloria Hetherington for their administrative and secretarial services.

GLOSSARY OF TERMS AND ABBREVIATIONS

E.N.L. - ELDORADO NUCLEAR LIMITED

I.C.D. - INTERNATIONAL CLASSIFICATION OF DISEASE

O.C.T.R.F. - ONTARIO CANCER TREATMENT AND RESEARCH FOUNDATION

W.L.M. - WORKING LEVEL MONTH - the dose of alpha radiation received by working for 168 hours in an air concentration of radon daughters of one working level. A working level is equivalent to 1.3 x 10 MeV of potential alpha energy per litre of air, (Band et al 1980).

RADIATION - The use of the word 'RADIATION' refers to alpha radiation, unless otherwise specified.

RELATIVE RISK - The relative risk of a particular disease for a given exposure is the probability of acquiring that disease given that the subject is exposed divided by the probability of acquiring the disease given that the subject is not exposed.

ODDS RATIO - The odds ratio is an estimate of the relative risk.

1. STUDY SETTING

1.1 Background:

In 1932, Eldorado Gold Mines Limited commenced operation of a plant in Port Hope, Ontario, to process the ores mined at Port Radium, Northwest Territories for the recovery of radium. In 1944, the company was taken over by the Canadian Government and renamed Eldorado Mining and Refining Limited. A further name change occurred in 1968 with the renaming of the Company as Eldorado Nuclear Limited (ENL) (MacLaren Engineering, 1976).

The first residues from the radium recovery operation were produced in 1933 and were disposed of on the plant site from 1933 to 1939. From 1939 to 1944, residues were deposited in the Lakeshore Residue Area (See Map, Appendix I). This area is a short distance to the west of the plant and is adjacent to a railway embankment just south of the CNR freight shed (since demolished). In the latter part of the 1939-1944 period, the nature of the residue changed as the plant processes were altered from radium extraction to the production of uranium. Approximately 4,000 to 5,000 tons of radium extraction residues were removed from the Lakeshore Residue Area in 1957 and 1958 and sold to Vitro Corporation in the United States for the recovery of other metals, the remaining residue was transferred to the Port Granby Residue Area, 10 miles west of Port Hope (MacLaren

Engineering, 1976).

The Monkey Mountain Residue Area within the town of Port Hope was used from 1945 to 1948 for the disposal of residue and large quantities were removed from this site and disposed of at Port Granby in 1959 and 1966. Some 800 tons of this residue were sold to Deloro Smelting and Refining Company in 1959. The Welcome Residue Area, about three miles to the northwest of Port Hope, was used from 1948 to 1954. About 4,000 tons of residue from this site was sold in 1956 to the Vitro Corporation in the United States for the recovery of other metals, and again in 1959 and 1960 about 1,000 tons of "geiger picker" rejects were sold to Deloro Smelting and Refining. During the early 1950's approximately 900 tons of speiss was also sent from Port Hope to Deloro (MacLaren Engineering, 1976).

The Port Granby Residue Area was first used in 1955 and remains the principal disposal area at the present time.

From 1948 to 1974, the Pidgeon Hill Storage Area was used for the storage of contaminated equipment and radium waste, and some incineration of combustible wastes was carried out prior to 1954, but no burial of waste was made on this site (MacLaren Engineering, 1976).

1.2 Investigation of Contaminated Sites in Port Hope

Investigation by ENL staff of the earlier residue disposal practices revealed that there were areas within the town of Port Hope that could have become contaminated. Possible contamination could have resulted from any of the following causes:

(i) spillage of residue during shipment by road to disposal areas, or during loading at the rail docks;

(ii) during the 1940's residues were stored in a variety of locations awaiting recovery of other materials (e.g. cobalt and silver) and it was possible that these temporary storage locations could have become contaminated;

(iii) there were several periods during which there was an active building programme on the ENL property. In 1938 and 1939 a building which had contained the original radium processing plant set up in 1932 was demolished. The refining of radium ceased in 1953 and in the following two years the radium laboratories were dismantled and buried at the Welcome Residue Area. In 1954 and 1955, the old radium circuit was removed and a new solvent extraction circuit installed; at about this time, several other buildings were demolished. In 1959, the original main office building and the uranium processing building were demolished.

All of these actions produced building rubble, fill and reclaimed building materials, any of which might have been used in the Town for various purposes.

(iv) surface run-off from the Monkey Mountain Residue

Area in particular may have resulted in contamination of the surrounding area, (MacLaren Engineering, 1976).

As a result of the above, ENL conducted an investigation during the late summer of 1975 which included interviewing long-term employees, searching plant records, and inviting assistance from local citizens through advertisements in the local newspaper and on the local radio station. Notwithstanding this investigation, the Atomic Energy Control Board (AECB) and the Ontario Ministry of Health (OMH) concluded in December, 1975 that a more systematic approach to the problem was called for. As a result, it was decided to conduct a complete survey of the Town to search for higher-than-normal levels of external radium and, if such areas were found, to delineate the areas with a survey on foot and, finally, to take selective air samples inside buildings and homes for radon analysis.

To accomplish this survey, a very sensitive detector was borrowed from the Chalk River Nuclear Laboratories of Atomic Energy of Canada Limited. This detector was mounted initially on an Ontario Ministry of Health vehicle and eventually transferred to an AECB vehicle in order to carry out a street-by-street survey of the whole community. Whenever abnormal radiation levels were detected, the Ontario Ministry of Health was notified and arrangements were made to collect air samples within buildings for careful analysis at the Ministry's laboratories in Toronto (MacLaren Engineering, 1976).

The systematic road survey commenced in late December, 1975 and was completed in March, 1976.

In early February the AECB established an office in Port Hope to co-ordinate the survey work. A system was established whereby external gamma radiation surveys of properties and buildings would be performed on request. These surveys were followed by air sampling when abnormal radiation levels were detected.

As a result of these surveys and the surveys performed by ENL, some 433 site surveys were documented to March 26, 1976, (MacLaren Engineering, 1976).

2. FEASIBILITY STUDY

In the autumn of 1980, National Health and Welfare and the Ontario Ministry of Health established a joint Federal/Provincial Committee to consider the issue of adverse health effects due to the disposal of radioactive waste in Port Hope. This committee contracted first, a feasibility study, and second, a large-scale health study.

The Feasibility Study was conducted to:-

(1) determine whether it would be possible to conduct a large scale health study, given certain design criteria, and

(2) propose an appropriate design study.

To this end the information sought included the availability, accessibility, cost and limitations of obtaining health data, mortality data, general demographic data and local data. The usefulness of local data was particularly important to assess in order to identify and trace individuals.

Each group participating in the feasibility study was invited to submit a proposal to the Ontario Ministry of Health. The Health Services Research Unit (HSRU), Queen's University received the contract in April, 1981, to conduct a case-control study of lung cancer in the town. This study was identified as PHASE II of Schedule C: Terms of Reference (15 September, 1980) of Request for Proposal RFP 80-01. (Ontario Ministry of Health, Health Programs Division, Toronto).

3. TERMS OF REFERENCE

The 'Terms of Reference' for the study were listed by the Federal/Provincial Committee for a Study of Port Hope in September, 1980. The Health Services Research Unit submitted a proposal to undertake PHASE II of the Project, the 'Terms of Reference' for which are reproduced below.

Phase II - Case-Control Study of Lung Cancer

Purpose: This study would attempt to evaluate the relative importance of domestic radiation exposure in the causation of lung cancer. Lung cancer is the major cancer known to be caused by exposure to radon and radon daughters. This study would control for the influence of smoking whereas the PHASE I study would not.

Cases: These would consist of residents of Port Hope who developed or died of lung cancer during the past ten years. Surviving cases would have to be identified through various sources including local hospitals and physicians. It is known that there were thirty-three (33) deaths due to lung cancer among residents of Port Hope during the period 1966 to 1977 inclusive. One might expect up to fifty (50) cases in the past ten (10) years if both deaths and surviving cases are included.

Controls: There would be two controls for each case matched by at least sex and age. In addition, it would be useful to match for smoking history since smoking is a major cause of lung cancer.

Exposure History: Radiation exposure would be estimated using:-

(a) data available from J. F. MacLaren Limited of Toronto, based on radiation survey of Port Hope; and
(b) the length of residence in the household.

Interview: A questionnaire would be designed and administered to surviving cases, controls and relatives of decedents. The questionnaire would include items on smoking habits, lifetime occupation(s), lifetime places of residence, medical history and family history. It is desirable to have all the interviews conducted by one trained interviewer.

Analysis: Statistical analysis should include calculation of odds ratios based on appropriate radiation exposure categories. The Supplier should be prepared to calculate odds ratio adjusted for one or more confounding variables.

In the 'General Guidelines' of the Schedule C, the Federal/Provincial Committee required:

"Since employees of Eldorado Nuclear Company Limited have been exposed to mixed sources of radiation, it is proposed that they (but not their families) be excluded from this Project".

4. METHOD

4.1 START UP ACTIVITIES:

4.1.1 Local -

The Study Team spent a great deal of time in "public relations" work with the residents of Port Hope. This was secondary to the scientific aspect of the study but was essential in view of the public attitudes encountered by the team at the start of the project. Strong emotions existed in the town and were openly expressed when initial approaches were made by the investigators. Rejection and open hostility were encountered. Full community co-operation was considered essential to the satisfactory conduct of the study. Meetings were arranged with the mayor, and conferences held with members of the press. Information letters were distributed within Port Hope, describing the nature of the study and listing the personnel in the study and their willingness to answer questions, (Appendix 2).

A meeting was arranged at the Port Hope Hospital with local physicians to solicit their co-operation with the study. The questionnaire was discussed and a letter was distributed to each doctor (Appendix 3). Additional information letters were then sent to Cobourg and Port Hope doctors listed in the Canadian Medical Directory who did not attend the information meeting. Follow-up attempts to determine the physicians' current addresses were made for undelivered letters.

Discussions were held with the Executive Directors and Medical Record Technicians of the local and area hospitals (Port Hope, Cobourg and Peterborough). Permission was obtained to examine and abstract the institutions admission/discharge cards. This was essential since information on these cards was needed in order to locate potential subjects who would then be asked to participate.

While the hospital authorities were very willing to co-operate fully, it was learned that the patient records at Port Hope Hospital had been destroyed and none were available prior to 1972. This information had implications for the identification and selection of non-cancer controls. It had originally been intended that one non-cancer patient would be matched to each case.

4.1.2 Ontario Cancer Treatment and Research Foundation

Although the initial discussions with the Ontario Cancer Treatment and Research Foundation (O.C.T.R.F.) during the feasibility study indicated that access to cancer registry files would be possible, an unanticipated three month delay was encountered while awaiting additional approval of the Sub-committee on Confidentiality. While the O.C.T.R.F. had patient records extending back to 1964, uniformly recorded computerized files existed only from 1969 onwards. This appeared to present no problem since the study called for a study of cases in the most recent ten year period. The feasibility study had shown that records for the period 1969 to 1979 were incomplete. Later O.C.T.R.F. data had either not been entered into the Foundation's computer file or was awaiting completion.

4.1.3 Staff

The Interviewer and Research Assistant were hired and the necessary training in interview techniques, and data collection methods was initiated by the Project Director.

4.2 QUESTIONNAIRE DEVELOPMENT AND TESTING:

The stages of the questionnaire development were -

4.2.1 Deciding and rationalizing general areas to be covered by the questionnaire, e.g. demographic, education, residence, etc.

4.2.2 Developing and wording questions that enabled the team to collect the information adequately and clearly.

4.2.3 Pilot testing the questionnaire. The pilot testing took place in two settings to accomplish two goals. The first involved faculty and staff of the Department of Community Health and Epidemiology and enabled the study team to obtain professional criticism on design and format.

It was also tested among ambulatory elderly patients who visited the Family Medicine Clinic in Kingston. An older population was necessary to pretest the questionnaire since it was anticipated that most of the interviews would be conducted with individuals over 50 years of age. Questions that were too lengthy, had confusing wording or complicated answer choices were modified.

4.2.4 Training of Interviewer. The training was conducted by the Project Director, a Nurse, with formal experience in interviewing and counselling technique. The need for discretion and sensitivity was emphasized because many interviews were in connection with the next-of-kin of recently deceased subjects. Ensuring confidentiality was also stressed.

Interview pre-tests with members of the Department of Community Health and Epidemiology were tape recorded and reviewed by the study team, providing feedback to the Interviewer. The first five interviews among actual study subjects were monitored by the research assistant who had previous interviewing experience and were determined to be adequately administered and recorded.

4.2.5 Questionnaire reliability was tested by having the interviewer and research assistant conduct repeated interviews at different times. Reliability (test-retest) ranged from 80-95%. Face validity was determined after the pilot interviews; volunteers were asked to comment on difficult or ambiguous questions, (see Questionnaire - Appendix 4).

4.3 IDENTIFICATION OF CASES

For the purpose of the study, a 'case' was defined as: "Any individual who developed or died of lung cancer (ICD 162) between 1969 and 1979, and who lived for at least seven years, prior to the year of diagnosis, within the Town of Port Hope".

The seven year residence period was agreed to in discussion with the Federal/Provincial Committee. This time period was selected on the grounds that seven years is likely the shortest possible latent period for lung cancer development following radon exposure.

The main source of potential cases was the Cancer Registry maintained by the O.C.T.R.F. Separate cancer notification files from pathology reports, hospital separations, incidence reports, cancer clinics, death registry and O.H.I.P. (hospital insurance), were merged. The O.C.T.R.F. created a single file from which individuals meeting the study's criteria could be drawn.

In order to locate any potential cases not known to the O.C.T.R.F. local physicians were solicited for names of patients with lung cancer.

4.3.1 Criteria for Selecting Potential Cases from OCTRF:

Potential cases were extracted from the merged OCTRF file using the following criteria: All those individuals who died or who had a diagnosis of lung cancer (ICD 162) made between 1969 to 1979. A wide selection was made by choosing individuals who were listed as residing in Durham County before 1974 and after 1974 in Northumberland County, (i.e. the counties that included the Town of Port Hope). This selection yielded 296 potential cases.

For these potential cases, the O.C.T.R.F. provided the following information: Name, Date of Birth; sometimes a current or former address; County of residence at first notification; ICD Number(s); Ontario Hospital Insurance Number; a hospital name with an admission and discharge date; Date of death, or last date known alive.

4.3.2 Verification of O.C.T.R.F. Cases

From the information provided by the O.C.T.R.F. lists of potential cases, who had been admitted to a particular hospital, were made. After obtaining permission from the hospitals' executive director, the Medical Records Department was given this list and asked to verify the patients' identities against the hospitals' admission/discharge records. At some hospitals the verification was done by the study Interviewer or research assistant, who was granted direct access to the hospitals admission/discharge cardex file. Name, date of birth, and sex were used to confirm identity.

Of the initial 296 potential cases, 243 were eliminated because they were residents of areas surrounding Port Hope and did not meet the residence requirements. A further 26 were eliminated or disqualified for reasons shown in Table I.

For the remaining potential cases the name of each patient's family physician was recorded. Where not available, the attending specialist was contacted and asked to provide the name of the family physician.

4.3.3 Tracing of Potential Cases

Lists of potential cases, who were patients of particular family physicians, were compiled and presented to the appropriate M.D. either at a meeting or over the telephone. At this time the study was re-explained and the physician was asked to confirm that the identified individuals were indeed their patients. If the patient was still alive or the doctor knew surviving next-of-kin, the physician was asked to telephone them and obtain permission for an interview by the study interviewer.

Three weeks after the initial list of names had been distributed to the doctors, a phone call was made by the project director or research assistant to follow-up on the progress. Thereafter follow-up was every week by the Interviewer who was stationed in Port Hope or by the research assistant at Queen's University.

In some cases the doctor did not know the next-of-kin, but was able to provide names and last known address or phone number of surviving next-of-kin. Since Port Hope is a small town, the physician's nurse often could provide information on the current address. Searching the local phonebook also yielded several names.

If still unsuccessful, the area Health Unit's Public Health Nurses (PHN's) were approached. This latter source was extremely fruitful, as many of the study subjects' next-of-kin were older and had come in contact with a PHN or related service (arthritis, physiotherapy, home care, etc.). As a last resource we went to the last known address and neighbours of the next-of-kin or study subject and inquired about the name or whereabouts of the next-of-kin. Obviously tracing became more difficult if we were trying to trace children or more distant relatives, especially if resident outside Port Hope.

4.4 INTERVIEWING CASES

If the physician was able to secure permission for the interview, the project director telephoned the individual contacted to explain the purpose of the study. The content of the questionnaire and time required to complete it was discussed. The personnel involved were noted. Confidentiality, and the methods to maintain it, were stressed. If the individual agreed, an appointment for the interview was established. For the individuals not contacted by the physicians, the project director telephoned them directly, explaining the study and making appointments for interviews.

A choice of interview locations was given, either in the Study Office in downtown Port Hope or the study subject's home.

In all but two situations, interviews were conducted at the subject's home. The interview usually took more than one hour to complete. The interview session began by presenting an information letter and any further questions were answered. The Interview and Medical Record Access Consent forms (Appendix 5 and 6) were read, and if the subject agreed, they were signed. The questionnaire was then administered. An information letter was left with them for future reference (see Appendix 2).

Seven potential cases were disqualified from the study at the interview stage because the results of the questionnaire indicated that the individual in question had not lived for a minimum of 7 years in Port Hope prior to the diagnosis of lung cancer.

4.5 TRACING OF CASES

A second round of tracing potential cases was carried out later in the study to examine those individuals who had initially refused to participate, or had not been located. The next-of-kin of two cases were located by calling all people in the Toronto telephone book with the last name of the next-of-kin. Five of the six who had initially refused to participate when contacted by their physicians, agreed to participate when reapproached by the members of the study team.

For a summary of the reason for disqualification or elimination of potential cases, see Table 1.

4.6 SELECTION OF CONTROLS

Two controls were matched for sex and date of birth (plus or minus five years) for each case. To be eligible as controls, individuals had to have resided in Port Hope for at least seven years and at least one of these years had to be during the seven-year period prior to the matched cases diagnosis of lung cancer. The proposal submitted by the investigators, and accepted by the Federal/Provincial Committee, called for the matching of one dead and one live control to each deceased case and two live controls for each live case. This format was originally decided upon to overcome problems of recall by next-of-kin, as it was anticipated that most identified cases would be deceased.

4.7 IDENTIFICATION OF CONTROLS

Potential controls were drawn from the O.C.T.R.F. cancer registry and Port Hope physicians' files based on the following criteria, additional to the matching requirements already stated.

4.7.1 Individuals who died from or were found to have cancer between 1969 and 1979. Cancers of the respiratory tract were excluded and selections were made from the ICD 8 classifications 150-159; 180-189; 190-199, and 230-239.

4.7.2 Individuals identified by their family physicians and who fell into the criteria above or who were suffering from a non-malignant illness.

All but 21 controls were obtained from the O.C.T.R.F. list provided to us. Twenty-one patients were selected from a list provided by Port Hope Physicians. There was some potential for bias in the selection of these final 21 controls by this different method, but they were not available from O.C.T.R.F. files nor from local hospital records. Almost all physicians in Port Hope work from a single clinic building - it was felt that this would reduce the likelihood of geographic or socio-economic bias in selection. The selection of 21 community controls had also been considered but the mobility of people within Port Hope (3 house changes on average for the selected cases, range 1-11) made it difficult to do so in an unbiased way.

Nineteen controls were obtained from the physicians at the clinic, two from solo practice physicians.

4.8 VERIFICATION, TRACING AND INTERVIEWING OF CONTROLS

4.8.1 Verification of the controls identified from the O.C.T.R.F. took place 5 months after the case verification and used essentially the same techniques as used to verify potential cases. This time lag between cases and controls was necessary although not desirable because the O.C.T.R.F. could not provide both (cases and controls) at the same time. To do this would have meant a 4-5 month delay in the study. Bias was eliminated by providing Senes Consultants with a mix of cases and controls identified by a second code number linked to our identification number.

4.8.2 Tracing was less rigorous than that employed for cases, e.g., if normal follow-up did not yield an address, or the individual refused to participate, then this potential control was usually dropped. In other words, the individual was not followed to an out-of-town address or approached a second time if the first contact met with definite refusal. Another possible control would then be selected from the pool of names obtained from the O.C.T.R.F.

4.8.3 Interviewing Controls. Scheduling a control interview was similar to that for cases, except that appointments were made by the Interviewer instead of the project director. The first five telephone calls were monitored by the project director to ensure comparable and adequate technique for arranging an interview.

5. DATA COLLECTION

5.1 Personal Information

Personal information was obtained at interview (see Questionnaire, Appendix 4) from the study subject or next-of-kin of the deceased study subject, (or when the subject was alive, from an interview with the subject). In most cases, this first interview provided all information required on the questionnaire. In some situations, the next-of-kin were unable to provide complete information on such things as residence, smoking and drinking habits, or employment history. To obtain further information, other relatives or friends were interviewed, and for 8 subjects, archived phone books of Bell Canada, old utility records and, in one case, employment records were consulted to confirm addresses.

5.2 Medical Records

During the interview study subjects, or the next-of-kin of deceased subjects, were asked to sign a consent form granting the study team access to the subjects' medical records. Where they still existed, the records of cooperating family physicians and hospitals were examined. Where Princess Margaret, a Toronto based Cancer Treatment Hospital, was listed as a referring hospital, records were first examined there. From these sources, information on history of disease, medications, therapeutic or diagnostic radiation exposure, and smoking and drinking were abstracted (Appendix 7). Details of the course of any cancer was noted, including the dates of first investigation, treatments, biopsy, surgery and autopsy.

For the 21 non-O.C.T.R.F. controls, (Table 2), family physicians' records were reviewed to determine that the subjects were free of any excluded diseases. In most cases, further reference to hospital records was not made because of the completeness of family physicians' records and uncomplicated histories.

Test-retest for record abstraction was determined by selecting a 10% sample of records from a particular hospital which had been abstracted by the interviewer. The project director and research assistant reabstracted these records onto separate coding sheets and these were compared with those made by the interviewer. One hundred percent (100%) interobserver agreement was obtained.

No interobserver agreement tests were made for the work of the new research assistant, an experienced data abstractor, who abstracted records for 20 subjects.

5.3 Data Coding and Review

Selected data from medical records and interview forms were transferred to a data summary sheet by the research assistant (Appendix 8). This work was checked by the project director and executive director for accuracy. A final review of the collected data was also made.

Incomplete, ambiguous or inconsistent medical information was noted for 13 subjects. To resolve these problems the research assistant re-examined previously reviewed records.

Once the final decision for inclusion of a study subject was made, the data were transferred to a coding sheet and double checked for accuracy by the project director (Appendix 9).

Data for therapeutic and diagnostic radiation was determined to be too inconsistent and incomplete and was, therefore, not transferred to the coding sheet for analysis.

5.4 Estimates of Radiation Exposure

At the interview the location of all residences occupied and the duration of occupancy, for each case and control, was recorded. The interviewer and investigators were "blind" to the radiation levels which had been measured in Port Hope houses and had no knowledge of the exposures encountered by any of the cases or controls. That information was forwarded to Senes with subjects identified only by number and in a random sequence so that the domestic radiation dosage estimator was blind to the subject's status as case or control. The method used by Senes to reconstruct the accumulated dosage of alpha radiation is described in Appendix 10.

5.5 Corrected Radiation Exposure

The domestic exposure data in its raw form has certain limitations. Exposure can be considered as both 'background', that is, a natural dose of radiation received by a subject living in an uncontaminated home, and 'excess', that portion due to living in a house contaminated with materials from Eldorado Nuclear Limited.

Radon is a decay product of uranium-238 and is present as an impurity in practically every kind of building material. Radon is, therefore, given off in varying quantities from the walls or foundations of nearly every house (Fremlin, 1980).

It has been estimated that the mean radon level within Norwegian houses corresponds to an annual exposure to the occupants of 0.33 WLM for 24 hour occupancy (Stranden, 1980).

Senes estimated the total accumulated radiation exposure for subjects only while they resided in Port Hope; no allowance has been made in the raw data for radiation exposures while living outside the town.

Had matching for total years residence in Port Hope been possible, this would have posed no problem and total exposures, whether background or background plus excess, would be directly comparable.

Senes Consultants Limited were contracted to estimate the accumulated Port Hope domestic alpha radiation dosage of the cases and controls. The method of dose reconstruction employed by them is reproduced in Appendix 10. Appendix 10 is the "Report on the Reconstruction of Radon Daughter Exposure for Persons Included in Case Control Study in Port Hope, Ontario" (Senes Consultants Limited, 1983, Toronto).

From the Senes data it appears that the 'non-problem home' in Port Hope had a background alpha radiation potential annual exposure level of 0.229 WLM. That level would be found in a B1 rated home and was the lowest annual WLM measurement in any of the homes occupied by study subjects.

Background domestic radiation levels in Port Hope are not markedly different from those in other parts of the country (Senes, 1983), see Appendix 10.

To estimate total Port Hope background radiation for each subject, the following formula was applied:-

$$0.229 \times 0.85 \text{ (or } 0.6\text{)} \times A \text{ years} = Y$$

where 0.85 or 0.6 is the occupancy factor used by Senes. 'A Years' - number of years lived in Port Hope after 1933, i.e. the date from which exposure data were collected.

The product 'Y' was subtracted from the raw domestic dosage to provide a corrected dosage. By this means no background radiation dose was included in the estimated dosage for any subject and overcame the problem of varying periods of residence in Port Hope.

The estimated total corrected dosages, referred to later in this report and used in the analysis, represent individual dosage above the background dose which everybody receives. Background radiation has thus been discounted.

Eldorado Nuclear Limited assisted the investigators by

(a) providing estimates of accumulated alpha radiation exposure for all persons who were selected as cases and controls and who had previously worked for the corporation,

and (b) conducting a linkage search to confirm that final cases and controls had not worked for the corporation. Persons of whose employment by E.N.L. we had no knowledge, were identified by that linkage.

6. DATA ANALYSIS

The estimates of individual cumulative radiation exposure should not be taken as absolute values. Some of the house measurements were made by single point or grab samples, while others were determined after serial sampling. It is known that considerable fluctuations in radon gas levels may occur at the same site over time, even in the absence of extraneous factors. The reader is advised, therefore, to take the cumulative exposures in working level months and the intervals used in the analysis merely as indications of low, medium or high exposures above background.

The findings of previous studies and the recommendations of the Beir Report suggest that a minimum 10 year latency period applies in the association of lung cancer with exposure to radon gas (Beir III Report, 1980). The tables presented in this report are, therefore, based on a 10 year latency period.

Although cumulative occupational exposures to alpha radiation were obtained for persons employed at the Eldorado Nuclear plant in Port Hope, we feel there must be doubt about the absolute accuracy of the reported levels. Because of the known association of lung cancer with high levels of alpha radiation, we felt that to obtain pure domestic exposures unadulterated by exposures in other sites, all persons who worked at E.N.L. should be excluded from the analysis, as was indicated in the Terms of The Reference*. The removal of E.N.L. employee cases and E.N.L. employee controls, with their matched pairs, resulted in the loss of 9 cases and 23 controls. Matched sets were dropped when:

---

* Since E.N.L. employment could only be ascertained after subject interview or record linkage, it was not an exclusion criteria for case or control selection.

1. the case had worked at E.N.L. (8 sets);
2. both controls, but not the case, had worked at E.N.L. (1 set).

Individual controls were dropped from a matched set when they had worked at E.N.L. but where the second control and the case had not. This left 5 sets with only 1 control.

When these exclusions were made a total of 76 individuals were available for analysis, 27 cases and 49 controls.

After coding, the data were entered into a microcomputer and transferred to the University's mainframe I.B.M.

Statistical analysis and the construction of graphs was undertaken using the Statistical Analysis System (SAS) Programme. With the exception of Table 8, all odds ratios, chi-squared statistics, significance values and confidence limits were determined using conditional (i.e. matched) logistic regression. This was facilitated by the SAS procedure PHGLM. Contingency table analysis was used in Table 8.

The association between domestic exposure and lung cancer was examined in three ways. The first two treated exposure as a dichotomous variable. The dichotomies were "zero W.L.M." versus "non-zero W.L.M." (Table 9), and "lived in a problem home" versus "did not live in a problem home" (Table 10)*. The third treated the logarithm of (W.L.M. + 1) as a continuous variable (Table 11). The logarithm was deemed necessary to remove the skewness. One was added to W.L.M. since the logarithm of 0 is undefined.

---

* The categorization of homes into "problem" and "non-problem" was made by Senes of Senes Report.

7. RESULTS

The distributions of correct domestic radiation exposure and log transformed exposures, are illustrated graphically in Figures 1 and 2. Figures, 3, 4 and 5 provide demographic data on the cases and matched controls.

Table 2 shows the source of controls and their distribution between the Ontario Cancer Treatment and Research Foundation and local physician-patient lists. Table 3 illustrates the sites of cancers in the control population. In Table 4 the histological characteristics of the lung cancer cases are noted.

Tables 5 and 6 demonstrate the percentage distribution of cases and controls in relation to corrected domestic exposure levels, and the percentage distribution of cases and controls for log transformed corrected domestic radiation exposures.

From the various sources of information on potential cases, 296 individuals were notified to us. After disqualification or elimination for a variety of reasons, only 27 subjects were left for inclusion in the project and the data analysis. The reasons for disqualification or elimination of notified potential cases are illustrated in Table 1.

The results of the data analysis are illustrated in Tables 7 to 11. The first two tables (7 and 8) demonstrate the association of lung cancer with cigarette smoking, while the other 3 tables show the association of lung cancer with corrected domestic radiation exposure in Port Hope homes.

The analysis in which exposure is dichotomized as "zero W.L.M." versus "non-zero W.L.M." is found in Table 9. When smoking is controlled for, a marginally significant (p = 0.057, one-sided) positive association is observed between exposure and lung cancer.

The analysis in which exposure is dichotomized as "lived in a problem home" versus "did not live in a problem home" is found in Table 10. A strong confounding is observed between exposure and smoking. The four exposed cases are smokers and the two exposed controls are not. When smoking is controlled for, a marginally significant (p = 0.050) positive association is again observed between exposure and lung cancer. Using conditional logistic regression, an adjusted (for smoking) odds ratio is determined to be 6.81 with a confidence interval of 0.513 to 90.6. The excessively wide confidence interval is due to the large variance of the estimated odds ratio caused by the extreme confounding between smoking and exposure. The odds ratios estimated in Table 9 and Table 10 are not as inconsistent as the absolute values would indicate, 2.76 versus 6.81, respectively. Each is contained in the confidence interval of the other and the confidence interval in Table 10 includes the confidence interval in Table 9. As stated before, extreme confounding has led to an estimate of the odds ratio in Table 10 with a large variance and it should be viewed with skeptism.

The logistic analysis model is described and illustrated on page 33-B.

The analysis in which the log transformed W.L.M. is analysed as continuous variable is found in Table 11. When smoking is controlled for, a significant (p = 0.014) positive association is abserved between exposure and lung cancer.

Table 12 illustrates the frequencies and mean accumulated alpha radiation of 18 E.N.L. employees (past or present) for whom the information could be obtained.

LOGISTIC ANALYSIS

X_1 = (1: exposed)
(0: not exposed)

X_2 = (1: smoker)
(0: non-smoker)

p = probability of individual being a case.

CRUDE:

$$\ln \frac{p}{1-p} = \beta_0 + \beta_1 X_1 \qquad \text{OR CRUDE} = \exp(\beta_1)$$

TABLE 9: $\hat{\beta}_1 = 0.437$
$s_{\hat{\beta}_1} = 0.498$

TABLE 10: $\hat{\beta}_1 = 1.17$
$s_{\hat{\beta}_1} = 0.875$

BY SMOKING:

$$\ln \frac{p}{1-p} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \qquad \text{OR ADJUSTED} = \exp(\beta_1)$$

TABLE 9: $\hat{\beta}_1 = 0.860$
$s_{\hat{\beta}_1} = 0.562$
$\hat{\beta}_2 = 3.24$
$s_{\hat{\beta}_2} = 1.08$

TABLE 10: $\hat{\beta}_1 = 1.92$
$s_{\hat{\beta}_1} = 1.32$
$\hat{\beta}_2 = 3.28$
$s_{\hat{\beta}_2} = 1.62$

TABLE 1

REASONS FOR DISQUALIFICATION OR ELIMINATION OF POTENTIAL CASES

REASON/SOURCE	#	SUB TOTAL	TOTAL
(Eliminated by verification against admission files at):			
COBOURG GENERAL HOSPITAL	16		
PORT HOPE GENERAL HOSPITAL	9		
BOWMANVILLE MEMORIAL HOSPITAL	6		
PETERBOROUGH GENERAL HOSPITAL	41		
KINGSTON CANCER CLINIC	13		
ST. JOSEPH'S HOSPITAL	99		
PRINCESS MARGARET HOSPITAL	59	243	
(At end of phase two):			
REFUSED TO PARTICIPATE	1		
NEXT-OF-KIN COULD NOT BE LOCATED	4		
DID NOT MEET RESIDENCE REQUIREMENT	7		
SUBJECT COULD NOT BE LOCATED BUT MOST LIKELY NOT A LUNG CANCER	1		
DISQUALIFIED BECAUSE HAD A MESOTHELIOMA	1		
DISQUALIFIED BECAUSE NOT A PRIMARY LUNG CANCER	1		
CANCER-FREE - MADE A CONTROL	1		
ONE M.D. SUGGESTED CASE WAS DISQUALIFIED BECAUSE DIAGNOSED BEFORE 1969	1		
E.N.L. EMPLOYEES	9	26	
USED AS FINAL CASES FROM O.C.T.R.F.	27	27	
			296

TABLE 2

SOURCE OF CONTROLS

SOURCE	NUMBER
Ontario Cancer Treatment and Research Foundation	27
Originally an Ontario Cancer Treatment and Research Foundation Case	1
Port Hope Physician	21
TOTAL NUMBER OF CONTROLS =	49

TABLE 3

SITE OF CANCER - CONTROLS

SITE	I.C.D. (8)	NUMBER
OESOPHAGUS	150	1
STOMACH	151	3
COLON	153	4
RECTUM	154	3
GALLBLADDER	156	2
CERVIX	180	1
UTERUS	182	3
PROSTATE	183	1
BLADDER	185	5
KIDNEY	188	4
BRAIN	189	1
NO CANCER	191	20
		49

TABLE 4

HISTOLOGICALLY DETERMINED CELL TYPE OF LUNG CANCER CASES

CELL TYPE	NUMBER	PERCENT OF TOTAL
NOT KNOWN	10	37.0
ADENOCARCINOMA	6	22.2
SQUAMOUS	11	40.7
	27	

TABLE 5

DISTRIBUTION OF CASES AND CONTROLS BY CORRECTED DOMESTIC EXPOSURE

RANGES (WLM)	CONTROLS	CASES
0 =	49.0	33.3
0> to <1	32.7	29.6
1> to <2	12.2	14.8
2> to <4	6.1	7.4
4> to <8	0.0	3.7
8> to <16	0.0	3.7
16>	0.0	7.4
	100%	100%

TABLE 6

DISTRIBUTION FOR LOG-TRANSFORMED CORRECTED DOMESTIC RADIATION EXPOSURE

RANGE	CONTROLS		CASES	
LOG (WLM)	%	#	%	#
0	44.9	22	33.3	9
0> to <1	49.0	24	44.4	12
1> to <2	6.1	3	7.4	2
2> to <3	0.0	0	7.4	2
3> to <4	0.0	0	3.7	1
4> to <5	0.0	0	3.7	1
	100 %	49	100 %	27

TABLE 7

ASSOCIATION OF LUNG CANCER WITH CIGARETTE SMOKING

CRUDE*

	SMOKERS	NON-SMOKERS
CASES	25	2
CONTROLS	24	25

n = 76

Chi-square = 17.16
p = 0.000018 (1-sided)
O.R. = 19.73
Confidence Interval 2.55 to 153

* Using Conditional Logistic Regression

BY SEX**

MALES

	SMOKERS	NON-SMOKERS
CASES	17	0
CONTROLS	22	7

n = 46

FEMALES

	SMOKERS	NON-SMOKERS
CASES	8	2
CONTROLS	2	18

n = 30

SUMMARY STATISTICS

Chi-square = 15.5
p = 0.000043 (1-sided)
O.R. = 21.0
Confidence Interval 2.54 to 173

** Using Conditional Logistic Regression and Controlling for Exposure.

TABLE 8

ASSOCIATION OF LUNG CANCER WITH CIGARETTE SMOKING STATUS

	CURRENT SMOKERS	QUIT FOR 10 YEARS	NON-SMOKERS
CASES	23	2	2
CONTROLS	19	5	25

n = 76

Pearson Chi Square = 16.25
(1-sided) $p < 0.0002$

Chi Square for Linear Trend = 16.23
(2-sided) $p = 0.0001$

	CRUDE ODDS RATIO
QUIT SMOKERS VS NON-SMOKERS ----------	5.0
CURRENT SMOKERS VS NON-SMOKERS ----------	15.13
CURRENT SMOKERS VS QUIT SMOKERS ----------	3.0

TABLE 9

ASSOCIATION OF LUNG CANCER WITH CORRECTED DOMESTIC RADIATION EXPOSURE

CRUDE *

	> 0 WLM	0 WLM
CASES	18	9
CONTROLS	27	22

n = 76

Chi-square = 0.79
p = 0.19 (1-sided)
O.R. = 1.55
Confidence Interval 0.584 to 4.11

* Using Conditional Logistic Regression Analysis

BY SMOKING**

	SMOKERS		NON-SMOKERS	
	> 0 WLM	0 WLM	> 0 WLM	0 WLM
CASES	16	9	2	0
CONTROLS	10	14	17	8

SUMMARY STATISTICS

Chi-square = 2.51
p = 0.057 (1-sided)
O.R. = 2.36
Confidence Interval 0.786 to 7.11

** Using Conditional Logistic Regression and Controlling for Smoking

TABLE 10

ASSOCIATION OF LUNG CANCER WITH RESIDENCE IN "PROBLEM" AND "NON-PROBLEM" HOMES

CRUDE*

	PROBLEM HOME	NON-PROBLEM HOME
CASES	4	23
CONTROLS	2	47

n = 76

Chi-Square = 1.94
p = 0.082
O.R. = 3.23
Confidence Interval .580 to 17.9

* Using Conditional Logistic Regression Analysis

BY SMOKING**

	SMOKERS		NON-SMOKERS	
	PROBLEM HOME	NON-PROBLEM HOME	PROBLEM HOME	NON-PROBLEM HOME
CASES	4	21	0	2
CONTROLS	0	24	2	23

Chi-Square = 2.69
p = 0.0505
O.R. = 6.81
Confidence Interval .513 to 90.6

** Using Conditional Logistic Regression Analysis

TABLE 11

ASSOCIATION OF LUNG CANCER WITH CORRECTED DOMESTIC EXPOSURE*

Exposure as a Continuous (Log-Transformed) Variable

CHI-SQUARE (1 d.f.)	1-SIDED P
4.89	0.014

* Using Conditional Logistic Regressing and Controlling for Smoking

W.L.M.	Estimated Odds Ratio
0	1
1	2.05
5	6.36
10	11.89

TABLE 12

ACCUMULATED INDUSTRIAL ALPHA RADIATION OF 18 E.N.L. EMPLOYEES

	ACCUMULATED ALPHA RADIATION
	0
	0.02
	0.32
	0.43
	4.0
	6.3
	6.45
	6.58
	10.06
	25.81
	26.58
	32.24
	40.31
	40.42
	80.93
	142.6
	248.31
	467.28
MEAN	63.25

SOURCE: ELDORADO NUCLEAR LIMITED, OTTAWA.

FIGURE 1

DISTRIBUTION OF CORRECTED DOMESTIC RADIATION EXPOSURE

(10 Year Latency)

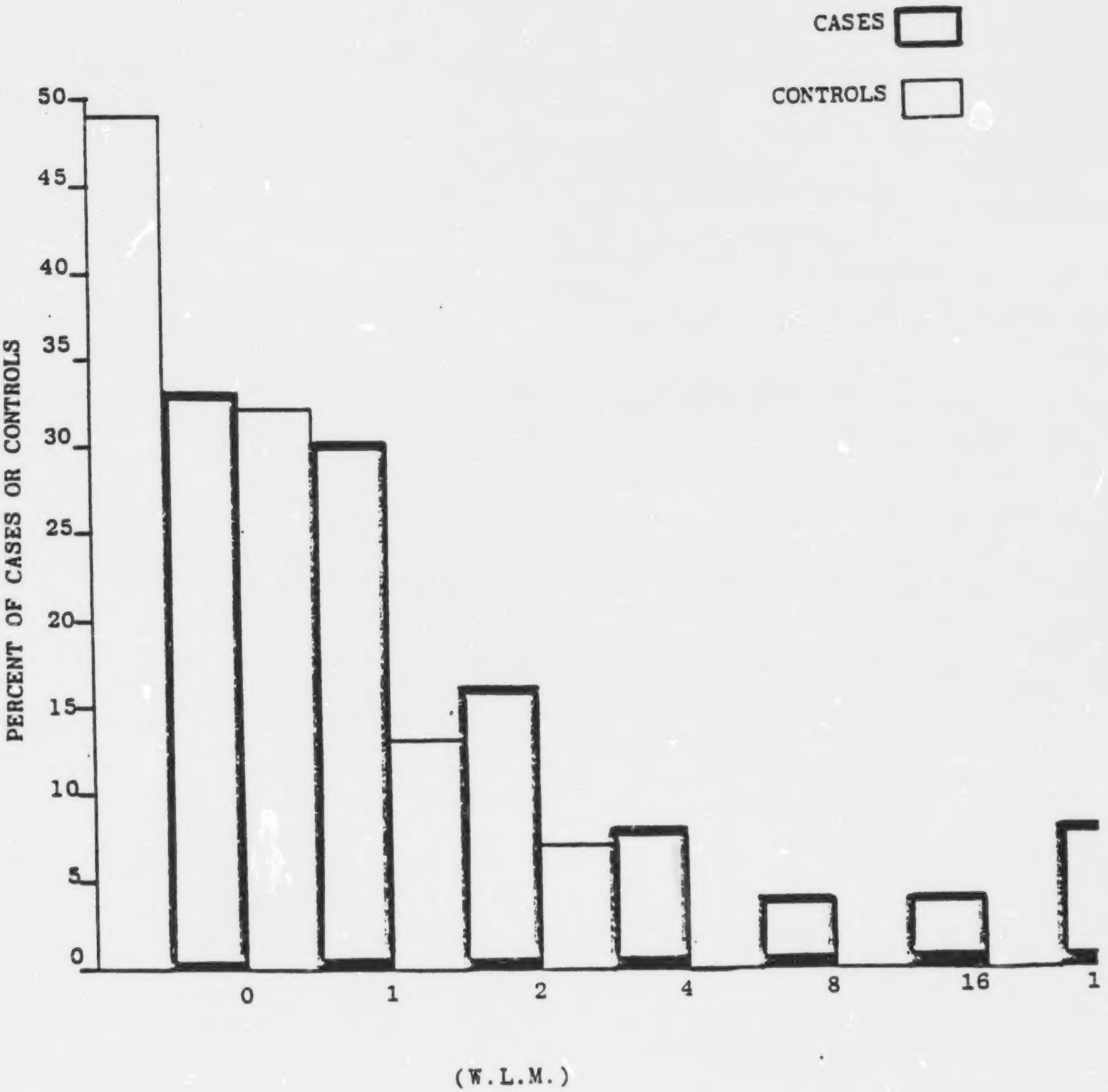


FIGURE 2

DISTRIBUTION OF LOG-TRANSFORMED CORRECTED DOMESTIC RADIATION EXPOSURE

(10 YEAR LATENCY)

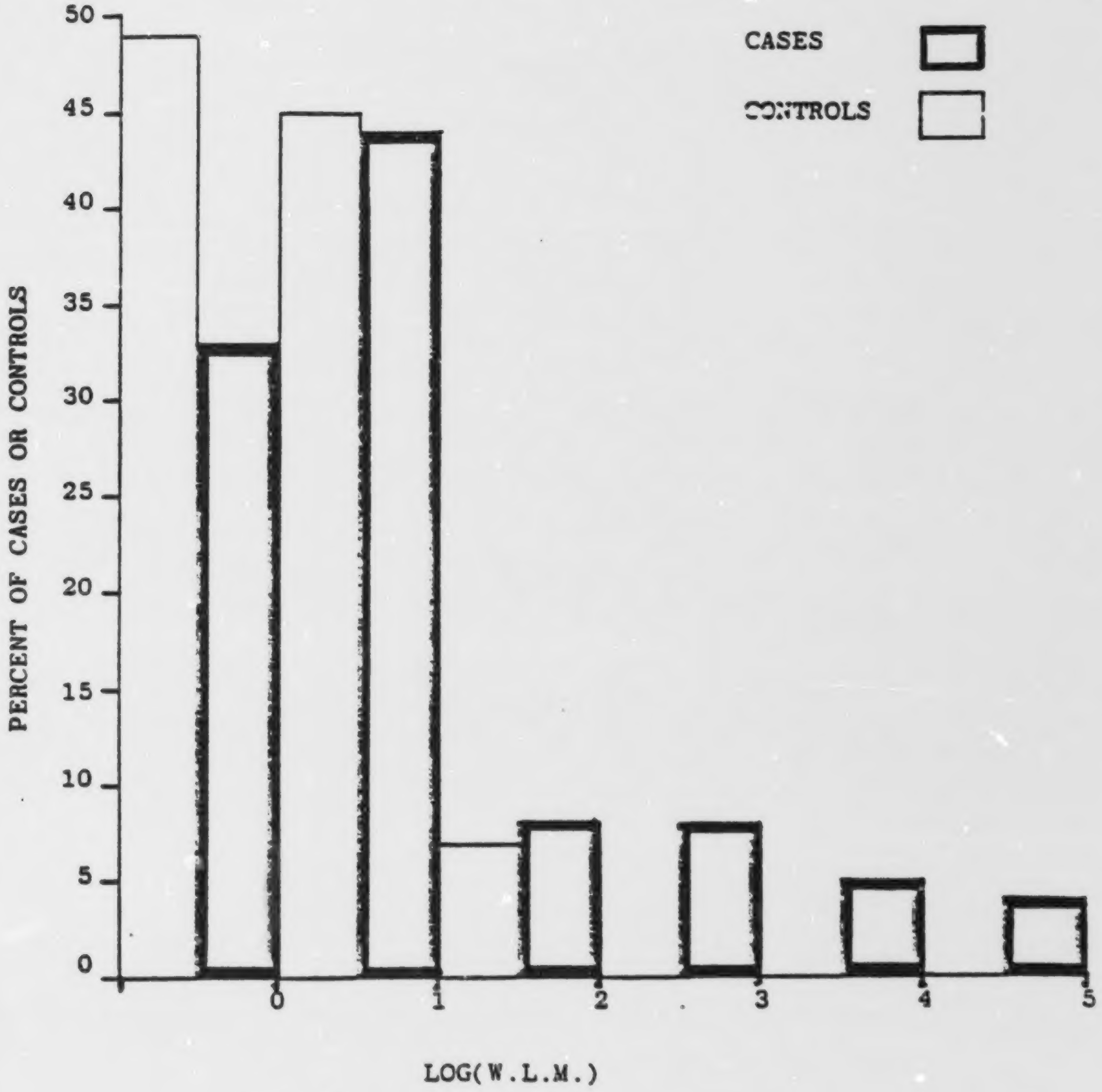


FIGURE 3

NUMBER OF LUNG CANCER CASES
DIAGNOSED FROM 1969 TO 1979

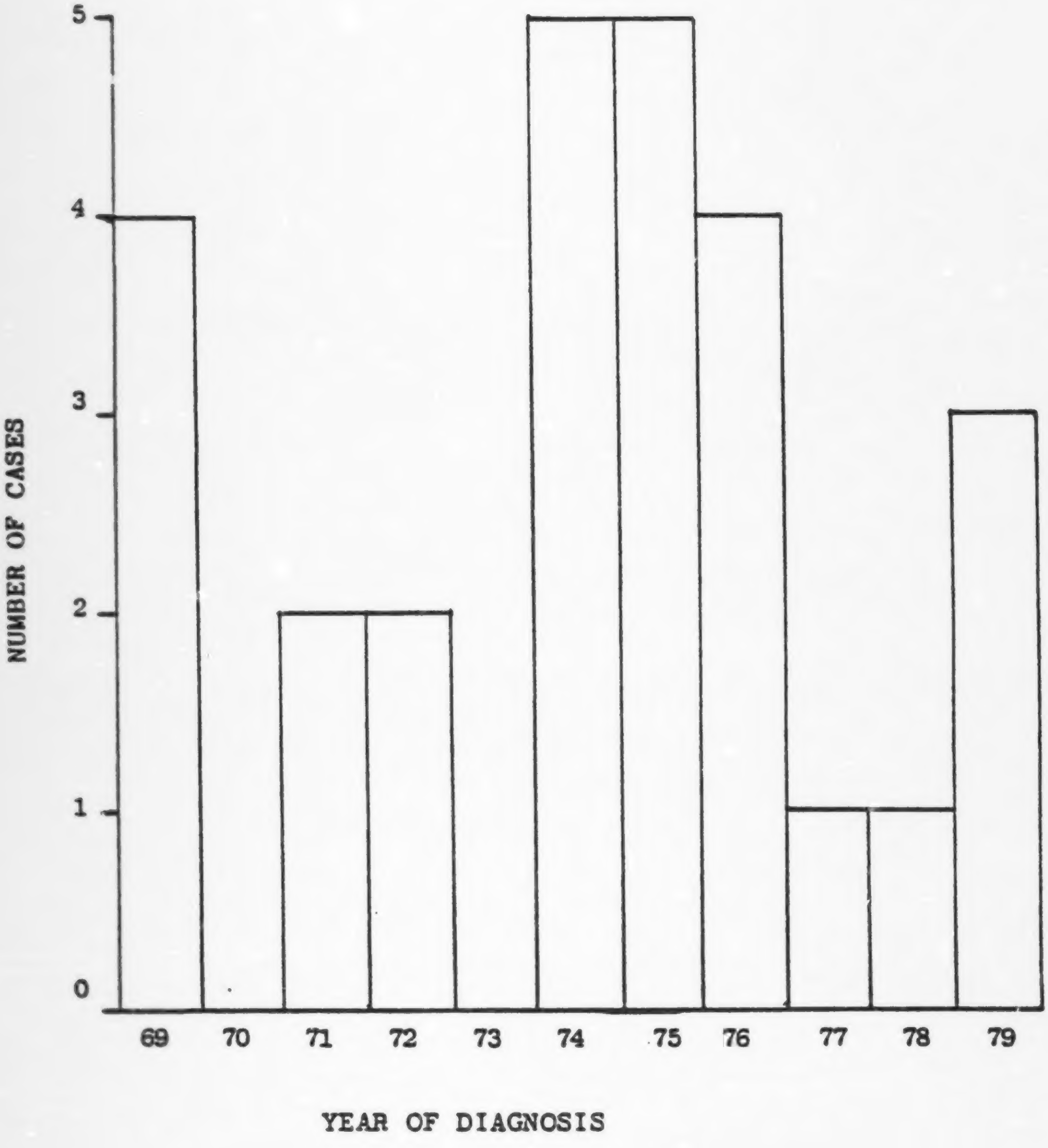


FIGURE 4

DIFFERENCES IN YEAR OF BIRTH BETWEEN CASES AND MATCHED CONTROLS

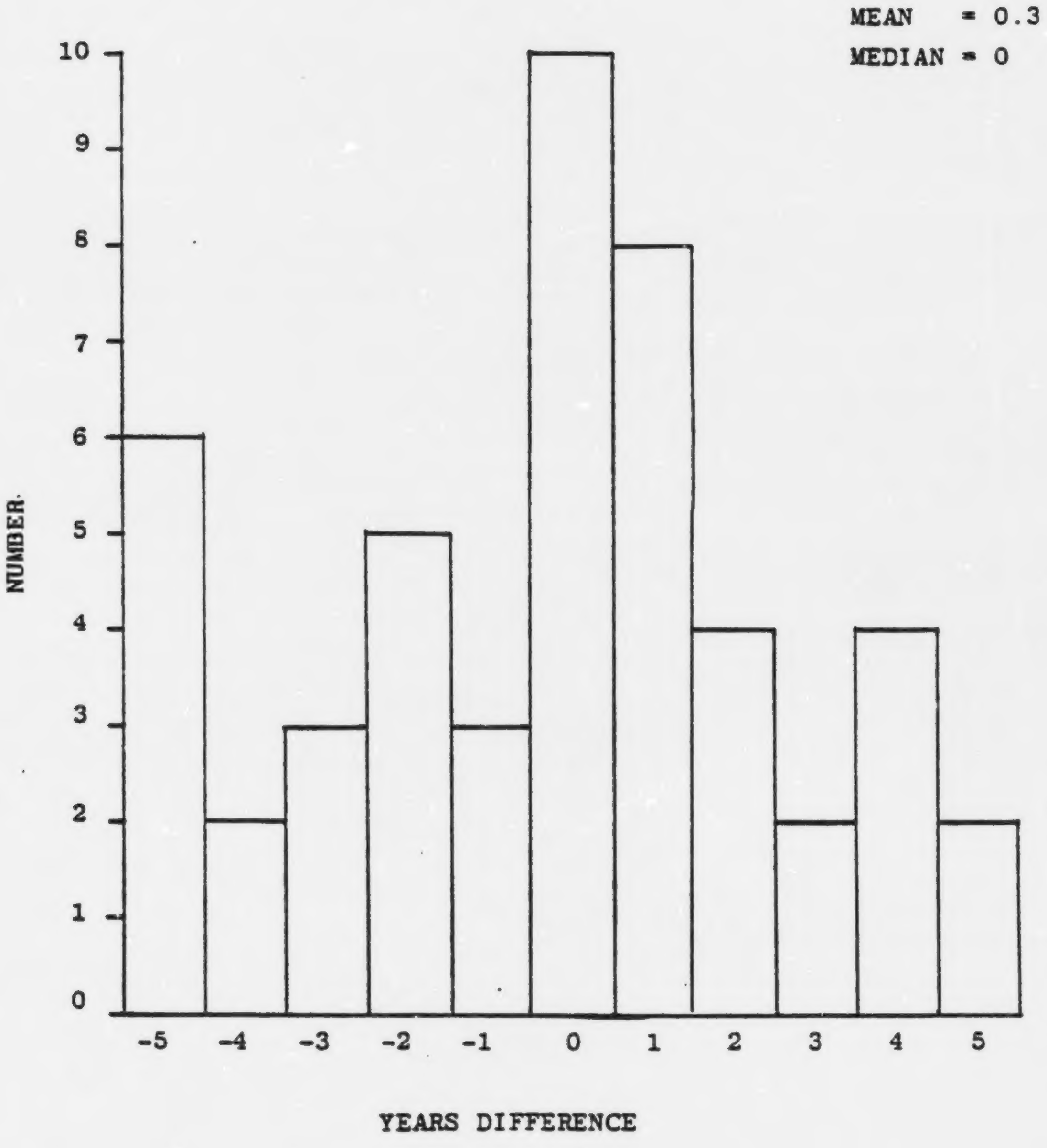
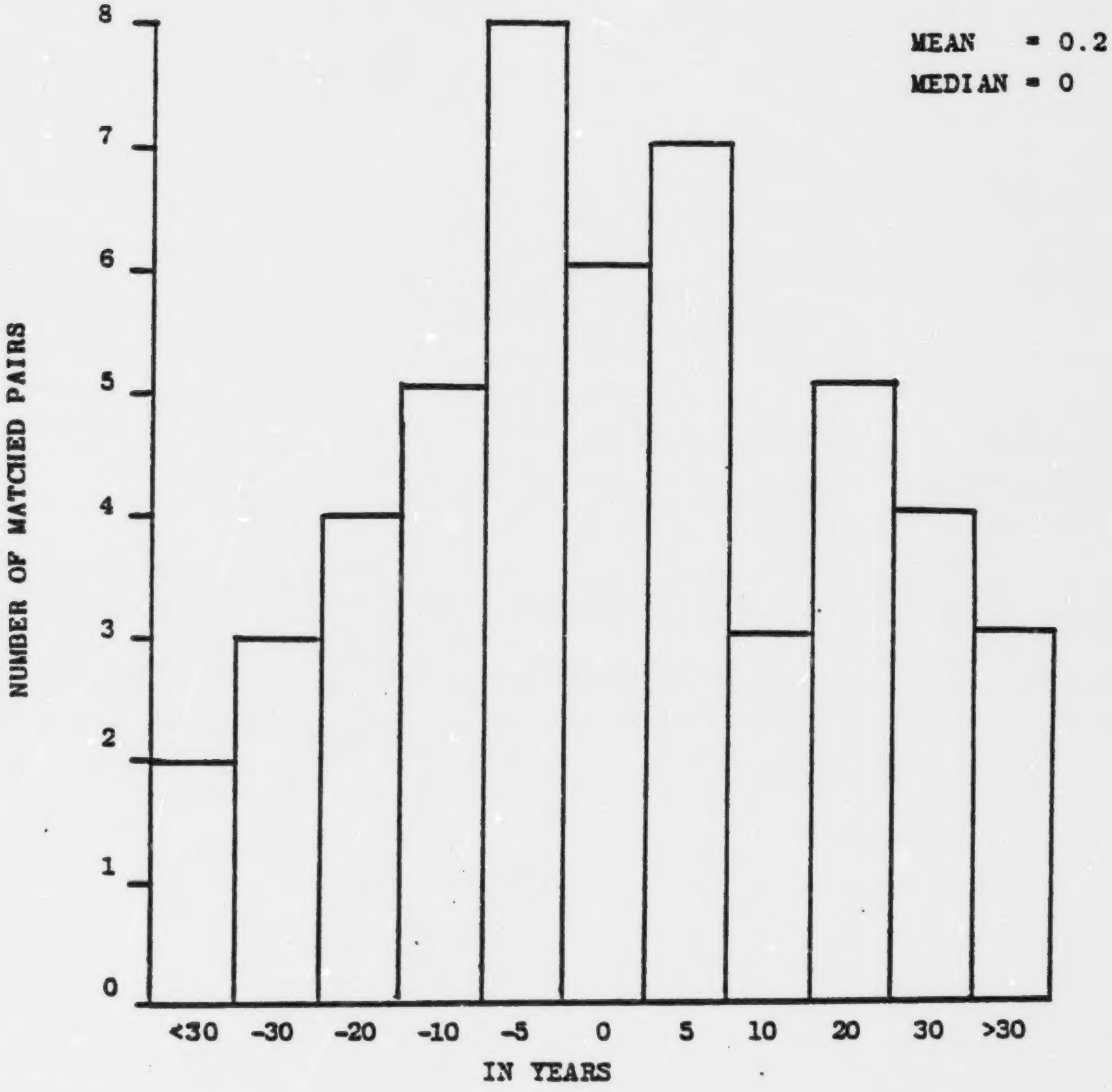


FIGURE 5

DIFFERENCES IN RESIDENCY IN PORT HOPE BETWEEN CASES AND MATCHED CONTROLS



(Negative indicates control resided longer than matched case)

8. DISCUSSION

The major problem facing studies of the health effects of low dosage radiation have been expressed by Barnaby, 1980, "Radiation induced cancers are indistinguishable from those due to other causes. The only way of linking a specific type of cancer with radiation is to compare an irradiative group with a non-irradiative but otherwise identical group and see if the incidence in the former is higher than in the latter. The snag is that an unambiguous result would require a high dose of radiation or an extremely large population exposed to a low dose". In this Port Hope study neither of the last stated requirements exists.

The lung is at particular risk of malignant change from alpha radiation, the type emanating from radon daughters formed in the process of degradation of U238 (Fremlin, 1980; Radford, 1982; McPherson, 1980). This is the type of radiation which was measured in Port Hope homes and which was used in the calculation of exposures during the course of the study.

Man is continually exposed to natural ionizing radiation. Modern building materials often contain high radium concentrations and thus emit radon daughters. Radium is one of the degradation products of U238. The atmospheric concentration of radon within homes is dependent on the materials used in construction, characteristics of the surrounding rock and fill, and the rate of internal ventilation. These factors were all taken into account by Senes Consultants in their reconstitution of potential radon daughter exposures of the subjects and controls used in the present study. Stranden, 1980 estimates that spending a 19-hour day within the average Norwegian home, gives the occupant an equivalent alpha radiation dose of 0.3 WLM per year. This is higher than the level we estimated as background in Port Hope (0.229 x 0.85 = 0.2 WLM).

The opinion that domestic exposure to greater than background levels of alpha radiation is associated with a higher odds ratio for lung cancer, is consistent with a report from Sweden by Axelson, et al, 1981 who have been studying lung cancer in persons exposed to higher than usual concentrations of radon in homes built on rock with a naturally high uranium content. Without correcting for cigarette smoking and by classifying radiation levels as background only or above background, these investigators produced data which showed a crude odds ratio for lung cancer associated with low levels of alpha radiation of 1.97.

Studies of American uranium miners who had been exposed to high concentrations of radon daughters showed no increase in relative risk of lung cancer with cumulative dosages below 120 WLM (Beir III Report). Canadian miners showed an increased lung cancer risk at much lower levels than that, the overall relative risk for the group being 1.8 (Beir III Report).

Studies among uranium and non-uranium miners exposed to radon daughters underground have shown excess mortality consistent with a linear dose effect relationship to the estimated alpha radiation exposure. Among non-uranium miners regression lines estimate excess lung cancer mortality at between 2.2 (Newfoundland) and 6.0 (United Kingdom) 10^{-6} per WLM year (Report by the United Nations Scientific Committee, 1977).

The National Research Council has formed the opinion from the analyses of many studies of alpha radiation exposure that the minimum latent period from radiation exposure to death from lung cancer is generally 10 years or more, with latency being inversely related to age at the time of exposure (Beir III Report).

All of these factors have been taken into account in establishing the criteria used in the analysis of the data from the Port Hope study. It has already been mentioned that employees of Eldorado Nuclear Limited have been excluded from the analysis and that only a 10 year latency period has been used. Eldorado Nuclear employees had alpha radiation exposures as a result of their occupational contact with sources of radiation. The objective of this investigation at Port Hope is to establish the influence of domestic exposure to alpha radiation, if there is any. In individuals the relative influences of occupational and domestic exposures to hazardous substances cannot be determined since the disease end point is the same and the proportionate responsibility, if disease occurs, cannot be estimated. The Joint Committee's decision to exclude E.N.L. employees from this study was correct.

Cigarette smoking is now an established cause of lung cancer with a very high risk ratio, approximately 12.0 in males. There is potentiation of cigarette smoking risk among uranium miners exposed to radon daughters, the risk increasing with both the duration of smoking and duration of radon exposure (Band, et al, 1980).

Our findings are consistent with those of previous studies demonstrating a crude odds ratio of smokers to non-smokers of 19.73. This is a highly statistically significant difference, which is consistent with the often quoted risk ratio of 12, making allowance for the small number of subjects and controls in the study.

When we looked at cigarette smoking, (association with lung cancer in relation to the smoking status of the individual) we found, as expected, an increasing odds ratio when "QUIT" smokers and "CURRENT" smokers were considered.

With the small numbers of cases and controls in this study the effect of cigarette smoking was completely confounding in the statistical analysis of differences between persons who lived in "problem" and "non-problem" houses (Table 10). This was due to the fact that no smoker controls and no non-smoker cases had lived in problem homes. The four individuals with the highest log transformed, corrected radiation exposures were cases and all were cigarette smokers.

Conditional logistic regression using radiation as a continuous variable did, however, show statistically significant risk increase with increasing exposure. Imprecision of measurements of radon daughter levels within homes has been mentioned previously. Since the estimates of total accummulation of alpha radiation exposure were made by Senes on data provided to them by another company, it may be unwise to place too much emphasis, if any, on the actual levels of estimated radiation expsosure. The investigators believe that the measurements of radon levels may not have been valid enough to allocate absolute radiation doses to individual persons but may only be sufficiently valid to categorize those likely to have had high or low exposures.

The application of necessarily rigid criteria in undertaking this case-control study of lung cancer in Port Hope resulted in small numbers of subjects. That, together with the low levels of cumulative radiation exposure experienced by the residents of Port Hope, makes it impossible to draw an unambiguous, clear-cut conclusion. While these data must be interpreted with considerable caution, some expression of opinion is called for. There is a suggestion from the data that the odds ratio of acquiring lung cancer after domestic exposure to above normal background radiation, and when cigarette smoking and sex are controlled for, is greater than unity (confidence limits 0.786 - 7.11).

The exposure dichotomized data analysis (Table 9) gave a difference of significance level between no extra exposure and extra exposure of $p = 0.057$. This p value is close to the value traditionally accepted as demonstrating statistically significant difference (0.05).

9. CONCLUSION

With regard to exposure resulting from radioactive contamination, the statistical analyses thus could not give coherent results and we do not feel they provide proof of an identifiable, increased risk of lung cancer from elevated alpha radiation levels in some Port Hope homes, when all of the other factors impinging on these results are considered. The very strong association between cigarette smoking and lung cancer was demonstrated in the study. Ninety percent of the cases were attributable to smoking.

REFERENCES

1. MacLaren, J.F. The Preliminary Investigation of the Technical and Economic Factors for the First Stage Remedial Measures at Port Hope. April 1976.

2. Fremlin, J.H. Health Effects from low level radiation. Ambio, 1980, 9, 60-65.

3. Stranden, E. Radon in dwellings and lung cancer. Health Physics, 1980, 38, 301-306.

4. BEIR III Report. The effects on populations of exposure to low levels of ionizing radiation. National Research Council, 1980. National Academy Press, Washington, D.C.

5. Barnaby, F. The controversy over low level radiation. Ambio, 1980, 9, 74-80.

6. Radford, E.P. Radioactivity in cigarette smoke. N.E.M.J., 1982, 307, 1449-1450.

7. McPherson, R.B. Environmental radon and radon daughter dosimetry in the respiratory tract. Health Physics, 1980, 39, 929-939.

8. Band, P. et al. Potentiation of cigarette smoking and radiation. Cancer, 1980, 45, 1273-1277.

9. The Effects of Atomic Radiation. Report by the United Nations Scientific Committee, 1977, Geneva.

10. Axelson, O. et al. Lung Cancer and radon in dwellings. The Lancet. Oct. 31, 1981, 995-996.

APPENDIX 1

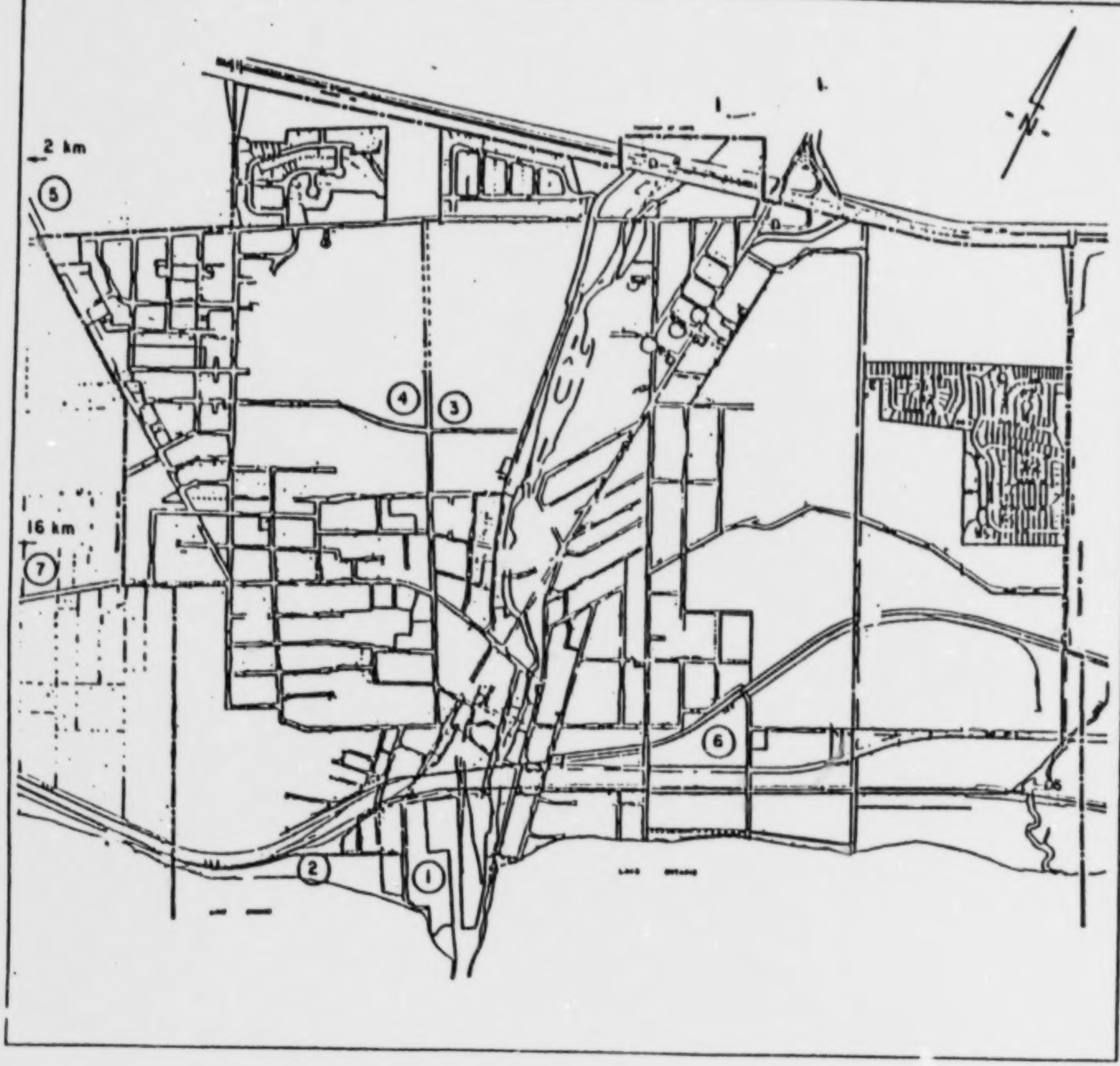


FIGURE 1·1

RESIDUE STORAGE
AND
HANDLING AREAS

1 PLANT SITE (1932-39)
2 LAKESHORE RESIDUE SITE (1939-44)
3 MONKEY MOUNTAIN RESIDUE SITE (1945-48)
4 PIDGEON HILL STORAGE AREA (1948-74)
5 WELCOME RESIDUE AREA (1948-54)
6 C.P.R. LOADOUT AREA (1950-60)
7 PORT GRANBY SITE (1966-)

APPENDIX 2

PORT HOPE HEALTH STUDY

DEPARTMENT OF
COMMUNITY HEALTH AND EPIDEMIOLOGY

Queen's University
Kingston, Canada
K7L 2N6

INFORMATION SHEET

A joint Federal Provincial Government Committee has commissioned a Study in Port Hope. The objective of this Study is to determine whether or not local radiation levels have had any adverse health effects on the town residents. The Department of Community Health and Epidemiology, Queen's University, Kingston was selected by that Committee to conduct this Study.

The Study will be conducted by interviewing selected samples of people from Port Hope and obtaining medical information with, of course, the consent of the persons interviewed and their physicians.

At no time will a medical examination of the selected persons be required nor will there have to be any diagnostic tests made on them. Personal physicians will be consulted and kept informed of the Study Team's actions at all times.

Existing records of radiation levels in homes and buildings in the town will have to be reviewed and, where incomplete, residents in the Study sample may be asked to allow access to their homes so that new measurements of radiation can be made.

Interviews should last about 20 minutes and will be voluntary. The results of these and the information obtained from medical records will be held in the strictest confidence. All of the information we collect will remain confidential and will be kept in a locked secure file. Individuals will be identified only by a code number; one master list will be kept in a secured file in the Department of Community Health and Epidemiology. Names or addresses WILL NOT be used or printed on any data forms.

The Study Team will have a local office in Port Hope and inquiries or concerns can be made at that office or to Mrs. Jan. Roberts at (613) 546-2849, Queen's University.

continued ..2

The members of the University who will be conducting this Study are:

R. Steele, M.D.,
R.E.M. Lees, M.D.,
T.O. Siu, Sc.D.,
J. Roberts, R.N..

In addition to these people, two staff members will be recruited to assist with interviewing and the collection of data.

APPENDIX 3

PORT HOPE HEALTH STUDY

DEPARTMENT OF
COMMUNITY HEALTH AND EPIDEMIOLOGY

Queen's University
Kingston, Canada
K7L 3N6

Dear Dr.

A joint Federal Provincial Government Committee has commissioned a Study in Port Hope. The objective of this Study is to determine whether or not local radiation levels have had any adverse health effects on the town residents. The Department of Community Health and Epidemiology, Queen's University, Kingston, was selected by that Committee to conduct this Study.

We shall be undertaking a case-control study of lung cancer hoping to identify all cases arising during the recent past years. Controls will be identified from, (a) persons who had cancers in other sites and (b) live neighborhood controls.

We hope to identify all cases from files of the Cancer Foundation and other data sources. Thereafter we might seek your co-operation and assistance in contacting identified cases or controls who are your patients or, in the instance of deceased patients, a surviving spouse or close relative. Essentially, we would be asking you to introduce our field staff and seek permission for a personal interview - most times this will be done by the Family Physician if he can be identified.

We shall be asking interviewees to sign a "consent to release of limited, relevant medical information" and thus might have to request your further assistance later.

At no time will a medical examination of the selected persons be required nor will there have to be any diagnostic tests made on them. Personal physicians will be consulted and kept informed of the Study Team's actions at all times.

Interviews should last about one hour and will be voluntary. The results of these and the information obtained from medical records will be held in the strictest confidence. All of the information we collect will remain confidential and will be kept in a locked secure file. Individuals will be

....2

identified only by a code number; one master list will be kept in a secured file in the Department of Community Health and Epidemiology. Names or addresses WILL NOT be used or printed on any data forms.

Existing records of radiation levels in homes and buildings in the town will have to be reviewed and, where incomplete, residents in the Study sample may be asked to allow access to their homes so that new measurements of radiation can be made.

The members of the University who will be conducting this Study are:

Robert Steele, M.D.
R.E.M. Lees, M.D.
T. Oswald Siu, D.Sc.
J. Roberts, R.N., M.Sc.

In addition to these people, two staff members have been recruited to assist with interviewing and the collection of data. They are, Martha Nosal, B.A., D.P.A., (Field Assistant) and Sherry Robinson, M.Ed. (Interviewer).

The Study Team will have a local office in Port Hope and inquiries or concerns can be made at that office (885-9349) or to Mrs. Jan Roberts at (613)547-6685, Queen's University.

I should add that all data obtained in connection with this study will be handled confidentially in accordance with the requirements of the Ontario Ministry of Health, Queen's Faculty of Medicine and the O.C.T.R.F.

I hope you will feel able to assist us if the need arises. If you have any questions about the study, please call Dr. Steele or myself at the above number.

Yours sincerely,

R.E.M. Lees, M.D., D.P.H.,
Professor

REML/gdh

APPENDIX 4

I.D. NUMBER _|_|_

PORT HOPE STUDY

INTERVIEW FORM

NAME OF CONTACT: ____________________ ☐

ADDRESS: ____________________

PHONE: ____________________

STUDY SUBJECT:

NAME: ____________________

ADDRESS (LAST KNOWN): ____________________

PHONE: (IF ALIVE) ____________________

DATE OF BIRTH: ____________________ ☐☐☐☐

FAMILY PHYSICIAN OR PHYSICIAN ATTENDED (CURRENT OR LAST KNOWN): ____________________

MOTHER'S MAIDEN NAME (FULL): ____________________

FATHER'S NAME: ____________________

DATE OF DEATH: ____________________

DATE OF INTERVIEW: ____________________

ID # ____________

I WOULD LIKE TO ASK YOU A FEW QUESTIONS ABOUT ____________ FAMILY IN THE EVENT THAT WE NEED ANY FURTHER INFORMATION. (SEE PROBES)

WHAT IS ____________ FIRST/NEXT CHILD'S NAME AND ADDRESS? (IF POSSIBLE GET PHONE NUMBER)

CHILD # 1

NAME: ____________________

ADDRESS: ____________________ PHONE: ____________________

CHILD # 2

NAME: ____________________

ADDRESS: ____________________ PHONE: ____________________

CHILD # 3

NAME: ____________________

ADDRESS: ____________________ PHONE: ____________________

CHILD # 4

NAME: ____________________

ADDRESS: ____________________ PHONE: ____________________

CHILD # 5

NAME: ____________________

ADDRESS: ____________________ PHONE: ____________________

ID # __________

SECTION I: THESE FIRST QUESTIONS ARE FOR LINKING INFORMATION

1. AGE ON LAST BIRTHDAY ☐☐

____

2. SEX ☐

____

3. MARITAL STATUS ☐

- __ 1. SINGLE
- __ 2. MARRIED
- __ 3. SEPARATED
- __ 4. DIVORCED
- __ 5. WIDOWED
- __ 6. COMMON LAW

4. CHURCH WE COULD GO TO FOR RECORDS (IE: BAPTISM, MARRIAGE)

NAME ______________________________

TOWN ______________________________

RELIGION ___________________________

SECTION II: THE NEXT QUESTIONS DEAL WITH WHERE _________ HAVE/HAD LIVED SINCE BIRTH:

5. IN WHAT CITY WERE/WAS ______________ BORN? ☐

CITY ______________________

PROV./STATE __________________

(GO TO CHART ON NEXT PAGE)

NOTE: Questions 3-13 NOT required for residency before 1940.

ID # ______ 4

#6 What was the first/next address ______ lived at in Port Hope? (Repeat until reach current address or address at time of death.)	#7 What years did ______ live there? (Specify date and # years.)	#8 Did ______ have fill put around the house? (from E.N.L.)	#9 Did ______ make any changes to the house? (renovations/ additions)	#10 If yes: were the building materials new or reclaimed (from E.N.L.)	#11 Was the house heated with coal oil or natural gas electricity	#12 Did the house have forced air?	#13 Did the house have air con- ditioning
1.	19__ to 19 __ # yrs.______						
2.	19__ to 19__ # yrs.______						
3.	19__ to 19__ # yrs.______						
4.	19__ to 19__ # yrs.______						
5.	19__ to 19__ # yrs.______						
6.	19__ to 19__ # yrs.______						
7.	19__ to 19__ # yrs.______						
8.	19__ to 19__ # yrs.______						
9.	19__ to 19__ # yrs.______						
10.	19__ to 19__ # yrs.______						

NOTE: Make sure that if a move away from Port Hope is indicated, you must find out if they moved within Durham County prior to 1973, or Northumberland County after 1973. If so, get addresses and years lived there.

I.D. #________

SECTION III: Next I would like to get some information about the schools ____________________ went to in Port Hope:

14. Did __________ ever go to school in Port Hope? ☐

___ 1. Yes

___ 2. No ⇒ If NO go to Question #18

___ 9. Don't know (if don't know, go to Question #18)

#15 What was the name of the first/next school ______ went to in Port Hope?	#16 What years did _________ attend this school? (Specify date & duration)	#17 What grade did _________ reach at this school?
1.	19__ to 19__ YRS. _________	
2.	19__ to 19__ YRS. _________	
3.	19__ to 19__ YRS. ________	
4.	19__ to 19__ YRS. _______	
5.	19__ to 19__ YRS. _______	
6.	19__ to 19__ YRS. _______	
7.	19__ to 19__ YRS. _______	
8.	19__ to 19__ YRS. ______	

18. Did _______________ have any other training in Port Hope, such as: Normal/Teachers School, Nursing, Apprenticeship, Technical training? (SPECIFY NAME, DURATION AND YEARS ATTENDED.) ☐

NAME: ________________ Duration & years ____________________ Training ___________

NAME: ________________ Duration & years ____________________ Training ___________

SECTION IV: Now I would like some information on ______________________ EMPLOYMENT HISTORY: I.D. # ____________
(INCLUDING FULL-TIME, PART-TIME, AND ARMED FORCES SERVICE)

#19 WHAT WAS THE NAME OF THE FIRST/NEXT PLACE ________ WORKED FOR:	#20 WHAT YEARS DID ______ WORK THERE? (SPECIFY DATE & DURATION.)	#21 WHAT CITY AND STATE/PROVINCE WAS THIS IN?	#22 WHAT DID ___ DO AT THIS JOB?	#23 WAS IT FULL-TIME OR PART-TIME EMPLOYMENT?	#24 DID THIS JOB INCLUDE THE USE OF (1) INDUSTRIAL CHEMICALS, (2) PROTECTIVE EQUIPMENT, IE: RESPIRATOR, BOOTS, SUITS, GLOVES, MASKS, BADGES, OR (3) OTHER HAZARDOUS ENVIRONMENTS, IE: MINING, DUST, RADIOACTIVITY?
1.	19__To19__ # YRS ___				
2.	19__To19__ # YRS.___				
3.	19__To19__ # YRS ___				
4.	19__To19__ # YRS.___				
5.	19__To19__ # YRS.___				
6.	19__To19__ # YRS				
7.	19__To19__ # YRS ___				
8.	19__To19__ # YRS				
9.	19__To19__ # YRS ___				
10.	19__To19__ # YRS ___				

NOTE: Have part-time, summer jobs and armed forces service been included?

SECTION V: NOW I WOULD LIKE TO KNOW A FEW THINGS ABOUT ____________________ HEALTH:

I.D. # ____________

⟹ INTERVIEWER INDICATE PRESENT HEALTH STATUS OF SUBJECT:

__ 1. DECEASED
__ 2. ILL
__ 3. HEALTHY

☐

25. DID __________ EVER HAVE AN ILLNESS THAT LIMITED _____ DAILY ACTIVITIES FOR MORE THAN 3 WEEKS AT A TIME?

__ 1. YES ⟹ GO TO CHART BELOW
__ 2. NO ⟹ GO TO QUESTION #32
__ 9. DON'T KNOW ⟹ GO TO QUESTION #32

☐

#26 WHAT WAS THE FIRST/NEXT MOST RECENT ILLNESS?	#27 HOW LONG DID IT LAST? (SPECIFY DATE & DURATION.) FROM TIME OF DIAGNOSIS	#28 WHO WAS THE PHYSICIAN THAT LOOKED AFTER ________ FOR THIS ILLNESS?	#29 WHERE DID THE DOCTOR SEE ________ FOR THIS ILLNESS?	#30 WAS _____ ADMITTED TO HOSPITAL FOR THIS ILLNESS? (SPECIFY HOSPITAL)	#31 WHY DID ________ GO INTO THE HOSPITAL?	INTERVIEWER COMMENTS
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						

#32 DID ______ EVER HAVE ANY X-RAYS? YES = 1, NO = 2, D.K. = 9	↓	#33 WHAT WAS THE MOST RECENT X-RAY AND WHERE WAS IT DONE? (HOSPITAL, CITY)		#34 WHEN DID ______ HAVE THIS MOST RECENT TEST? (SPECIFY YEAR)	
CHEST X-RAY ----------------				19	
BARIUM ENEMA ----------------				19	
BARIUM MEAL ----------------				19	
KIDNEY X-RAY (IVP) -----------				19	
BLADDER X-RAY ----------------				19	
FLUOROSCOPY ----------------				19	
THYROID X-RAY --------------				19	
OTHER (SPECIFY - IE: X-RAY --- FOR ACCIDENT (FRACTURES), ETC.)				19	

#35 DID ______ EVER HAVE RADIATION TREATMENTS? YES = 1, NO = 2, D.K. = 9	↓	#36 WHERE WAS IT DONE? (HOSPITAL, CITY)		#37 WHEN DID ______ HAVE THIS TREATMENT? (SPECIFY YEAR)	
ACNE --------------------				19__ TO 19__	
RINGWORM ----------------				19__ TO 19__	
FEMALE MENOPAUSAL SYMPTOMS ---				19__ TO 19__	
HEAD LICE ----------------				19__ TO 19__	
ANGIOMAS (BIRTH MARKS) -------				19__ TO 19__	
HERPES --------------------				19__ TO 19__	
CANCER ------------------				19__ TO 19__	
TUBERCULOSIS --------------				19__ TO 19__	
THYROID ------------------				19__ TO 19__	
MOLES/WARTS ---------------				19__ TO 19__	
BONE/BRAIN SCANS-------------				19__ TO 19__	
LIVER SCANS ---------------				19__ TO 19__	
OTHER (SPECIFY) -------------				19__ TO 19__	

38. DID ______ EVER HAVE A FOOT X-RAY IN A SHOESTORE? (IF YES, SPECIFY APPROXIMATE NUMBER OF TIMES.)

___ 1. YES ⇒ NUMBER OF TIMES ______ ☐ ☐☐

___ 2. NO

___ 9. D.K.

I.D. # ________

39. Do/did ____________ TAKE ANY STEROIDS FOR A PERIOD OF AT LEAST ONE MONTH? ☐
___ 1. Yes (I.E. CORTISONE, PREDNISONE, DEPO-MEDROL)
___ 2. No
___ 9. D.K.

40. Did __________ EVER SMOKE? (If YES, SPECIFY NUMBER OF YEARS.) ☐
___ 1. Yes Number of years ________ What years 19 to 19 ____________
___ 2. No
___ 9. D.K.

41. (IF YES): What do/did ______________ SMOKE? ☐
___ 1. CIGARETTES
___ 2. CIGARS
___ 3. PIPE
___ 4. Other (SPECIFY ______________________)

42. (IF SMOKES CIGARETTES): How many did/do ______________ SMOKE PER DAY? ☐☐
______________ NUMBER PER DAY

43. (IF SMOKES CIGARETTES): Did _______ EVER QUIT? (If YES, SPECIFY WHEN AND FOR HOW LONG) ☐☐☐☐☐
___ 1. Yes WHEN ____________ HOW LONG ___________
___ 2. No
___ 9. D.K.

44. What type of alcoholic beverages do/did ________ ENJOY? (If drinks, specify amount per day or week) ☐☐
___ 1. LIQUOR (1 DRINK = 1-1½ OZ) AMOUNT __________
___ 2. BEER (1 BEER = 1 PINT) AMOUNT __________
___ 3. WINE (1 GLASS = 4 OZ) AMOUNT __________
___ 5. DO/DID NOT DRINK --- IF DO NOT DRINK GO TO QUESTION # 48.
___ 9. D.K.

45. For how many years did ______ HAVE ALCOHOLIC BEVERAGES ON A REGULAR BASIS? NUMBER OF YEARS ☐☐

46. Did __________ EVER STOP DRINKING ALCOHOLIC BEVERAGES FOR ANY REASON? (If YES SPECIFY WHEN & FOR HOW LONG) ☐☐☐☐☐
___ 1. Yes WHEN __________________ HOW LONG ____________________
___ 2. No
___ 9. D.K.

47. Do/did ____________ ENJOY ANY HOBBIES, SUCH AS: ☐
___ 1. FLOWER GARDENING
___ 2. VEGETABLE GARDENING
___ 3. FRUIT GARDENING
___ 4. HOME REPAIRS/BUILDING
___ 5. FISHING
___ 6. OTHER (SPECIFY ____________)

SECTION VI: FINALLY, I WOULD LIKE TO ASK A FEW QUESTIONS ABOUT ____________ FAMILY:

I.D. # ________

48. DO/DID ________ HAVE ANY CHILDREN? (IF YES, WERE ANY ADOPTED?)

___ 1. YES NUMBER OF CHILDREN ______ ADOPTED ________
___ 2. NO
___ 9. D.K.

☐☐☐☐

49. (IF NO) WAS THIS BY CHOICE?

___ 1. YES
___ 2. NO
___ 9. D.K.

☐

50. HOW MANY PREGNANCIES DID ________ HAVE?

________ NUMBER OF PREGNANCIES
___ 9. D.K.

☐☐

51. DID ________ HAVE ANY MISCARRIAGES? (SPECIFY NUMBER)

___ 1. YES ________ NUMBER
___ 2. NO
___ 9. D.K.

☐☐☐

52. WERE ANY OF ________ CHILDREN PREMATURE? (SPECIFY WHICH)

___ 1. YES PREGNANCY NO. ________
___ 2. NO
___ 9. D.K.

☐☐☐

53. HOW MANY LIVE BIRTHS DID ____________ HAVE?

________ NUMBER OF LIVE BIRTHS
___ 9. D.K.

☐☐

54. DID ________ SMOKE AND/OR DRINK DURING ANY PREGNANCY? (SPECIFY AMOUNT, IF POSSIBLE IE: OCCASIONALLY, REGULARLY)

___ 1. YES, SMOKED DURING PREGNANCY # ________ AMOUNT ____________
___ 2. YES, DRANK DURING PREGNANCY # ________ AMOUNT ____________
___ 3. NO, DID NOT SMOKE OR DRINK
___ 9. D.K.

☐☐

55. DID ________ HAVE ANY MEDICATION OR INJECTIONS DURING PREGNANCY? (IF YES, SPECIFY MEDICATION & PREGNANCY)

___ 1. YES MEDICATION ____________ PREGNANCY # ______
MEDICATION ____________ PREGNANCY # ______
MEDICATION ____________ PREGNANCY # ______
___ 2. NO MEDICATION
___ 9. D.K.

☐☐☐

IF SUBJECT HAS CHILDREN GO TO CHART ON NEXT PAGE.
IF NO CHILDREN, PROCEED TO CONSENT FORM, ETC.

I.D. # ________________

REFER TO TEAR SHEET FOR CHILDREN'S NAMES	# 56 IS THIS CHILD ALIVE? (IF NO, SPECIFY CAUSE OF DEATH)	# 57 DATE AND PLACE OF BIRTH	# 58 HOW MANY YEARS HAS THIS CHILD LIVED IN PORT HOPE? (SPECIFY DATE & DURATION)	# 59 DID THIS CHILD EVER HAVE A HEALTH PROBLEM THAT LIMITED DAILY ACTIVITIES FOR MORE THAN 3 WEEKS AT A TIME? (IF YES, SPECIFY ILLNESS)	# 60 HOW MANY CHILDREN DOES THIS CHILD HAVE?	# 61 IF NONE, WAS THIS BY CHOICE?
CHILD # 1			19__ TO 19__ # YEARS ______			
CHILD # 2			19__ TO 19__ # YEARS ______			
CHILD # 3			19__ TO 19__ # YEARS ______			
CHILD # 4			19__ TO 19__ # YEARS ______			
CHILD # 5			19__ TO 19__ # YEARS ______			
CHILD # 6			19__ TO 19__ # YEARS ______			

THIS IS THE END OF THE INTERVIEW -- PROCEED TO MEDICAL RECORD CONSENT FORM AND THANK YOU, ETC.

APPENDIX 5

INTERVIEW CONSENT FORM

I, ______________________________, HAVE BEEN CONTACTED BY MY DOCTOR, ______________________________, AND AGREE TO BE INTERVIEWED BY A MEMBER OF THE PORT HOPE HEALTH STUDY TEAM OF QUEEN'S UNIVERSITY, KINGSTON, ONTARIO, FOR A STUDY OF THE HEALTH EFFECTS OF LOW LEVEL EXPOSURE TO ENVIRONMENTAL RADIATION CONTAMINATION. THE PURPOSE OF THE STUDY HAS BEEN EXPLAINED TO ME AND I HAVE RECEIVED AN INFORMATION LETTER. I UNDERSTAND THAT I DO NOT HAVE TO ANSWER ANY QUESTIONS IF I DON'T WANT TO, OR I CAN STOP THE INTERVIEW AT ANY TIME WITHOUT AFFECTING MY RELATIONSHIP WITH MY DOCTOR OR ANY OTHER PERSON ASSOCIATED WITH THE PROJECT.

I UNDERSTAND THAT THE INFORMATION WILL REMAIN CONFIDENTIAL. ALL DATA WILL BE KEPT BY THE DEPARTMENT OF COMMUNITY HEALTH AND EPIDEMIOLOGY, QUEEN'S UNIVERSITY, KINGSTON, IN A SECURE FILE. PERSONS WILL BE IDENTIFIED BY CODE NUMBER, SO IT WILL NOT BE POSSIBLE TO IDENTIFY INDIVIDUALS IN PUBLICATIONS AND FINAL REPORTS. THIS CONSENT FORM IS VALID UNTIL DECEMBER 31, 1982, AT WHICH TIME THE STUDY SHALL BE COMPLETED.

I UNDERSTAND THAT I MAY CONTACT THE INTERVIEWER, AT 885-9349, OR ANY MEMBER OF THE PROJECT TEAM, AT (613) 547-6685, IF I HAVE ANY QUESTIONS AFTER THE INTERVIEW.

SIGNATURE ____________________	
RELATIONSHIP TO STUDY SUBJECT ____________________	SIGNATURE OF WITNESS ____________________
DATE ____________________	DATE ____________________

APPENDIX 6

MEDICAL RECORDS RELEASE CONSENT FORM

I, ______________________________, AGREE TO THE RELEASE OF INFORMATION FROM THE MEDICAL RECORDS OF ______________________, TO BE COLLECTED BY THE PORT HOPE HEALTH STUDY TEAM. THE INFORMATION WILL BE OBTAINED FROM A PHYSICIAN OR HOSPITAL AND/OR CLINIC INVOLVED. THE INFORMATION WILL BE USED FOR THE SOLE PURPOSE OF THE AFORE MENTIONED STUDY, AND WILL REMAIN CONFIDENTIAL. IT WILL BE CODED BEFORE IT LEAVES THE PHYSICIAN'S AND/OR HOSPITAL PREMISES TO ENSURE THAT THE INDIVIDUAL CAN NOT BE IDENTIFIED BY NAME OR ADDRESS. ALL COLLECTED INFORMATION WILL BE KEPT BY THE DEPARTMENT OF COMMUNITY HEALTH AND EPIDEMIOLOGY, QUEEN'S UNIVERSITY, KINGSTON, ONTARIO, IN A SECURE FILE. THIS CONSENT FORM IS VALID UNTIL DECEMBER 31, 1982, AT WHICH TIME THE STUDY SHALL BE COMPLETED.

SIGNATURE ____________________	SIGNATURE OF WITNESS ____________________
RELATIONSHIP TO STUDY SUBJECT ____________________	DATE ____________________
DATE ____________________	

APPENDIX 7

MEDICAL RECORDS DATA SHEET

I.D. #____________________ SOURCE:____________________

DATE		DATE
	DIAGNOSIS:	
	PRIMARY LUNG CA?:	
	X-RAYS & TESTS (REASONS & RESULTS)	
	TREATMENT & MEDICATIONS	

CONSULTING PHYSICIANS

ADDITIONAL INFORMATION:

APPENDIX 8

I.D. CODE ________ SEX _____ PERSON INTERVIEWED ____ MS _____

YEAR OF BIRTH ______ YEAR OF DEATH ______ DATE OF DX __________

CELL TYPE ____

MEDICAL HISTORY	DATE	#	REASON
X-RAYS SUSPECTED			
LOW			
MEDIUM			
HIGH			

STERIODS

SUSPECTED ____

RECORDED ____

OBSTETRICAL HISTORY ____

OFFSPRING DISEASES

SMOKING HISTORY

DRINKING HISTORY

APPENDIX 9

ID ☐☐☐ 1 3

Match ID ☐☐☐ 4 6

Control Type ☐☐ 7 8

Case Type ☐ 9

Physician ☐☐ 11 12

Person Interviewed ☐ 13

D.O.S. ☐☐-☐☐ 14 17

D.O.D. ☐☐-☐☐ 18 21

Marital Status ☐ 23

Sex ☐ 24

Interview Date ☐☐☐☐ 25 28

Year Case Dx ☐☐ 30 31

Year Match Dx ☐☐ 32 33

Status ☐ 34

MEDICAL EXPOSURE

Low ☐☐ 35 36

Medium ☐☐ 37 38

High ☐ 39

Suspected Low ☐ 40

Suspected Medium ☐ 41

Steriods ☐ 43

Smoking ☐ 44

Pack-Years ☐☐☐ 45 47

Drinking ☐ 48

Cell Type ☐ 49

# of Pregs ☐☐ 51 52

# of Misc. ☐ 53

# of Premies ☐ 54

Choice ☐ 55

Offspring's Diseases ☐☐ 56 57

ENL X-Rays ☐☐ 58 59

ENL WLM Exposure ☐☐☐.☐ 61 64

ENL Gamma Exposure ☐☐.☐ 65 67

APPENDIX 10

REPORT ON THE RECONSTRUCTION OF RADON DAUGHTER EXPOSURE FOR PERSONS INCLUDED IN CASE CONTROL STUDY IN PORT HOPE, ONTARIO

by

SENES Consultants Limited
499 McNicoll Avenue
Willowdale, Ontario
M2H 2C9

MAY 1983

ACKNOWLEDGEMENTS

SENES Consultants Limited acknowledges the interest and suggestions provided by the late Dr. R. B. Sutherland, Dr. C. G. Stewart and Mr. L. R. Haywood during the development stages of this report.

We would also like to acknowledge the assistance of Mr. E. J. Chart, Mr. W. Bradley and Mr. S. Corras of MacLaren Engineers for their assistance in much of the computerized manipulation of the data.

While the assistance provided by the above are gratefully acknowledged, any logic errors and/or omissions which are contained in this document are solely the responsibility of SENES Consultants Limited.

TABLE OF CONTENTS

Page No.

1.0 INTRODUCTION 1-1

2.0 DESCRIPTION OF DATA BASE USED FOR RADIATION EXPOSURE ESTIMATION 2-1

- 2.1 History of Remedial Investigations 2-1
- 2.2 Residency Data 2-3
- 2.3 Characteristics of Radon and Radon Daughter Data Set 2-4
  - 2.3.1 Subdivision of data 2-4
  - 2.3.2 Seasonal Variation of Data 2-7
  - 2.3.3 Radon Data Uncertainties 2-9

3.0 APPROACH TO DOSE RECONSTRUCTION 3-1

- 3.1 General 3-1
- 3.2 Logic Plan for Dose Reconstruction 3-1
- 3.3 Summary of Data Characteristics 3-8
- 3.4 Effect of Latent Period 3-10

4.0 RESULTS 4-1

- 4.1 Results 4-1
- 4.2 Summary 4-1
- 4.3 Confounding Effects 4-2

REFERENCES

APPENDIX A DOSE RECONSTRUCTION ESTIMATES

LIST OF FIGURES

FIGURE	DESCRIPTION
1.1	Residue Storage and Handling Areas
2.1	Sample Residency Questionnaire
2.2	Distribution of Pre-Remedial Radon Data - By Sampling Location, Heating System, and Structure Designation
2.3	Distribution of Pre-Remedial Working Level Data - By Sampling Location, Heating System, and Structure Designation
2.4	Distribution of Radon and Working Level Data for Port Hope and Cross Canada Homes
2.5	Mean Monthly Equilibrium Ratio and Outdoor Temperature Measured in Port Hope for the Periods: December, 1977 to February 1979
2.6	Mean Concentration of Radon and Radon Daughters by Temperature for Non-Radon Problem Homes
3.1	Logic Plan for Dose Reconstruction
4.1	Distribution of Exposure Estimates for Zero Latency Option
4.2	Cumulative Frequency Distribution of Exposure Estimates for Zero Latency Option

LIST OF TABLES

Table No.	Description	Follows Page No.
1.1	History of Eldorado Operations: 1932 to 1975	1-1
2.1	Radon and Working Level Record Layout	2-3
2.2	Structure File Record Layout	2-3
2.3	Radon Data Dose Characteristics	2-5
2.4	Summary of Data Used in Development of Working Level - Temperature Correlation	2-8
3.1	Generalized Potential Annual Exposure to Non-Radon Problem Homes	3-6
3.2	General Annual Exposure Estimates for Non-Radon Problem Homes	3-7
3.3	Data Characteristics for Non-Radon Problem Homes	3-9
3.4	Data Characteristics for Radon Problem Homes	3-9
3.5	Non-Radon Problem Homes - Potential Annual Exposure	3-9
3.6	Radon Problem Homes - Example Exposure Estimate	3-10
4.1	Exposure Estimate Summary Statistics	4-1

1.0 INTRODUCTION

In 1932 Eldorado Gold Mines set up an operation at Port Hope, Ontario to refine Port Radium ores for the recovery of radium and by 1933 the first radium had been produced.

During the early 1940's the emphasis shifted from the recovery of radium to the recovery of uranium; however, it was not until 1953 that the refining of radium ceased. Table 1.1 outlines the history of the Eldorado operation from 1932 to 1975.

During the twenty year period from 1933 to 1953, residues from the radium recovery operation were deposited in several designated sites located throughout the town (Figure 1.1). However, following a 1975 investigation by Eldorado staff into earlier residue disposal practices, it became evident that several non-designated areas within the Town of Port Hope had become contaminated with refinery wastes.

Four possible causes for the spread of the contamination were identified (MacLaren, 1976):

i) spillage of residue during shipment by road to the residue disposal areas, or during loading at the rail docks;
ii) temporary storage of 1940's residues in a variety of locations awaiting recovery of other metals;
iii) salvage and distribution throughout the town of building materials, fill and rubble resulting from the various demolition campaigns carried out from 1938 to 1959;

TABLE 1.1

History of Eldorado Operations: 1932 to 1975

1932	Eldorado Gold Mines Operation Starts in Port Hope
1933	First Radium Produced
1933-1939	Radium Residues Disposed On Site
1938-1939	Demolition of First Radium Plant
1939-1944	Radium Residues Disposed of at Lakeshore Site
1942	Uranium Production at Port Hope Facility Begins
1945-1948	Radium Residues On Site Reprocessed
1945-1948	Residues Disposed of at Monkey Mountain Site
1948-1974	Pidgeon Hill Storage Area Used for Storage of Contaminated Equipment and Radium Waste
1948-1954	Residues Disposed of at Welcome Site
1951-1952	900 Tons of Speiss at Welcome Site Sold to Deloro Smelting and Refinery
1953	Radium Refining Operation Discontinued
1954-1955	Radium Circuit Removed and Buried at Welcome Site
1954-1955	Demolition of Several Process Buildings
1955	Port Granby Waste Management Site Opened
1957-1958	5000 Tons of Radium Extraction Residues from Lakeshore Residue Area Sold to Vitro Corporation, Remaining Residues Transferred to Port Granby Site
1959	Original Uranium Process Building Demolished
1959	800 Tons of Residue from Monkey Mountain Site Sold to Deloro Smelting and Refining
1959	Monkey Mountain Residues Transferred to Port Granby
1959-1960	1000 Tons Geiger Picker Rejects from Welcome Site Sold to Deloro Smelting and Refining
1966	Monkey Mountain Residues Transferred to Port Granby
1975	Eldorado Investigations Resulting in Remedial Program

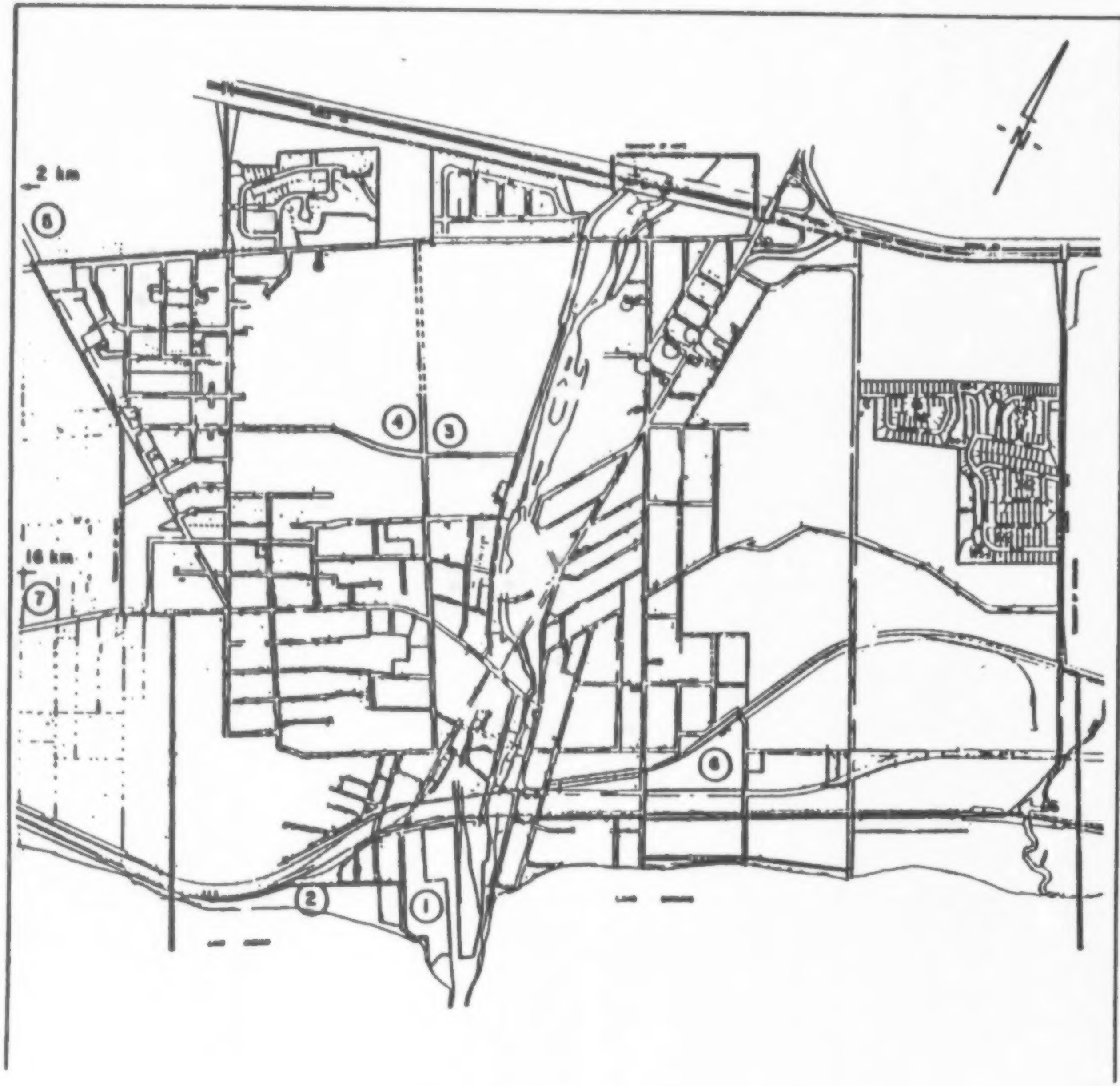


FIGURE 1·1

RESIDUE STORAGE AND HANDLING AREAS

1 PLANT SITE (1932-39)
2 LAKESHORE RESIDUE SITE (1939-44)
3 MONKEY MOUNTAIN RESIDUE SITE (1945-48)
4 PIDGEON HILL STORAGE AREA (1948-74)
5 WELCOME RESIDUE AREA (1948-54)
6 C.P.R. LOADOUT AREA (1950-60)
7 PORT GRANBY SITE (1955-)

iv) surface run-off from the Monkey Mountain Residue Area resulting in surface contamination of the surrounding area, particularly Pidgeon Hill.

In December 1975 the Atomic Energy Control Board and the Ontario Ministry of Health initiated a systematic and complete survey of the town. This survey involved the search for higher-than-normal levels of gamma radiation and the collection of selective air samples inside buildings and homes for radon analysis. By mid-1976 it became apparent that the problem was widespread, encompassing some 550 of the 3500 properties surveyed.

As the public became more aware of the problem, concern was raised with regard to the potential health effects of exposure to radiation due to environmental contamination. To resolve this concern, the Ministers of Health and Welfare Canada and the Ontario Ministry of Health agreed to co-sponsor an epidemiologic study to investigate the possibility of health effects, particularly in respect to cancers detectable in Port Hope residents, that could be attributable to ionizing radiation. In May of 1981 Queens University Department of Community Health and Epidemiology, in collaboration with SENES Consultants Limited was awarded a contract to perform a case-control study of the possible correlation between radiation and lung cancer in residents of Port Hope.

The role of SENES in this project was to provide an estimate of the accumulated domestic exposure to radon daughters measured in Working Level Months (WLM) for all cases and controls included in the study. These cases and controls were supplied to SENES in a "blind" fashion, without any form of category identification. SENES personnel were thoroughly familiar with the available radon and contamination data, having submitted in January 1981 a report to the Ontario Ministry of Health entitled, "Report on Environmental Data for a Health Study of Port Hope - A Feasibility Program to the Joint Committee for Health Study at Port Hope, Public Health Branch, Department of Health". (SENES, 1981).

This current report summarizes the development and results of the estimated radon daughter exposures for the 118 cases and controls identified by Queens. These estimates were based on specific case/control employment (where, how long) and residence (location, duration, heating system) information obtained by Queens during interviews with the next of kin or the actual study persons themselves. The data used for the dose reconstructions were based on the results of the remedial action investigations carried out during the period of 1976 to 1979.

2.0 DESCRIPTION OF DATA BASE USED FOR RADIATION EXPOSURE ESTIMATION

2.1 History of Remedial Investigations

As discussed earlier, a campaign was initiated in the spring of 1976, by the Atomic Energy Control Board, Eldorado Nuclear Limited and the Ontario Ministry of Health (now Ministry of Labour) to survey the entire town of Port Hope for radioactive contamination and to measure radon gas levels in occupied structures. Approximately 3500 properties were surveyed as part of this campaign with radon levels measured in 2960 structures. These surveys identified 550 properties as potential remedial work sites, requiring some form of follow up investigation to determine whether or not remedial work was in fact required.

As part of the remedial works program conducted during 1976 to 1980, detailed surveys were carried out on the 550 properties that had been initially identified as potential remedial work sites. Approximately 150 of the original 550 sites were determined to require no remedial work with the remaining 400 falling into one or more of the following categories:

Category	Number
exterior gamma levels above criteria[1]	280
interior contamination levels above criteria[2]	220
radon/radon daughter levels above criteria[3] (radon problem homes)	150

Of the 550 properties surveyed, approximately 400 underwent a complete pre-remedial investigation consisting of:

---

[1] 0.10 mR/h at 1 m above ground
[2] 0.05 mR/h at 0.5 m above localized area
[3] 7.0 pCi/L, 0.02 WL

- a set of radon and radon daughter measurements in the basement and main floor areas, usually on three separate days;
- a detailed interior gamma survey;
- a detailed exterior gamma survey based on a 3 m x 3 m grid system
- a detailed interior contamination survey (alpha, beta, and gamma measurements);
- a subsurface gamma survey (when necessary).

In terms of radon/radon daughter sampling, generally three sets of pre-remedial samples were collected under maximized conditions*to establish whether or not an above-criteria situation existed, thereby warranting some form of remedial work. When the remedial work was completed, a series of post-remedial radon and working level samples were collected. In some instances, as many as 10 sets of samples were collected to verify that the remedial work had been successful in reducing the radon daughter concentration to an acceptable level (less than 0.02 WL).

For each structure sampled as part of the remedial works investigations, several pieces of information were recorded in addition to the usual date, time, and location. This additional information included structure type (frame, brick), basement foundation (concrete block, fieldstone, poured concrete), heating system (forced air, oil or gas, non forced air-electric baseboard, space heater, gravity coal), outdoor temperature, barometric pressure, precipitation, interior temperature and relative humidity.

---

*closing windows and doors, etc. to measure the highest potential radon/radon daughter concentrations

In 1979 all the radon/working level data which had been collected from September 1976 to November 1979 were computerized to create a comprehensive data base on which to draw generalized or specific conclusions regarding any of the parameters measured. This data base contains 7570 specific radon and/or working level measurements. Table 2.1 outlines the information included in the radon and working level data base. Table 2.2 outlines the information in the specific structure data base.

Since the purpose of this study was to estimate the dose received by an individual due to exposure to radon daughters while resident in a specific structure, only pre-remedial radon sample results were considered to be applicable. Other sample types (i.e. post-remedial) were obviously not considered to be representative of the concentrations which may have existed in structures during the period of 1933 to 1976. Of the original 7570 radon and/or working level measurements incorporated in the data base, some 4620 measurements were classified as pre-remedial and thus suitable for use in this study. Section 2.3 describes the characteristics of this data set.

2.2 Residency Data

As part of the in-field data collection by Queens, residency information was recorded during the interviews with the next of kin or the controls themselves. A sample residency questionnaire is shown on Figure 2.1. From these completed questionnaires, 380 structures were identified as residences potentially requiring dose reconstruction estimates based on the selected periods of occupation.

TABLE 2.1

RADON AND WORKING LEVEL RECORD LAYOUT

Structure Identification Number

Sampling Date

Sampling Time

Outdoor Meteorological Conditions

- Relative Humidity
- Absolute Humidity
- Temperature

Indoor Conditions

- Relative Humidity
- Absolute Humidity
- Temperature

Sample Type

1 = Pre-Remedial
2 = Special Request
3 = Post-remedial Investigation*
4 = Post-Remedial*
5 = Passive Monitor*

Sample Location

MG = Main Floor General
MK = Main Floor Kitchen
SF = Second Floor General
BU = Basement General Unfinished
BC = Basement Crawl Space*
BS = Basement Cold Cellar*
BB = Basement Bedroom
BK = Basement Kitchen
BL = Basement Laundry Area
BF = Basement General Finished
BG = Basement General Unclassified
BJ = Basement Bathroom

Sample Collection

MX = Maximized
NM = Not Maximized
MS = Maximized, Smoker in Area
MC = Maximized, Cooking in Area
MU = Maximized, Unoccupied*

Radon Concentration

Working Level

Equilibrium Fraction

*Not suitable for use in this study

TABLE 2.2

STRUCTURE FILE RECORD LAYOUT

Structure Type

A - Apartment
B - Commercial & Residential
R - Single Family Dwelling
D - Semi-Detached
T - Townhouse
C - Commercial
I - Industrial
S - School
G - Church

Structure Type (Above Grade)

FR - Frame
BS - Solid Brick
BV - Brick Veneer
CB - Concrete Brick
LG - Log

Structure Age (years)

Basement Description

SB - Slab on Grade
CS - Crawl Space
FB - Full Basement
LB - Limited Basement
PB - Partial Basement
SL - Split Level

Foundation Type

PC - Poured Concrete
CB - Concrete Block
FS - Fieldstone
BR - Brick
NF - No Foundation
BF - Concrete Block & Fieldstone

Basement Floor

PC - Poured Concrete
BR - Brick
EA - Earth
CE - Concrete & Earth

TABLE 2.2 (continued)

Page Two STRUCTURE FILE RECORD LAYOUT

Basement Condition

CF - Completely Finished
PF - Partly Finished
UF - Unfinished
UH - Uninhabitable

Heating Type

EB - Electric Baseboard
FE - Forced Air-Electric
FO - Forced Air - Oil
FG - Forced Air - Gas
HO - Hot Water - Oil
HB - Hot Water Gas
SP - Space Heater
WD - Wood Stove
GW - Gravity Wood
GO - Gravity Oil
OW - Oil and Wood

Air Conditioning

Humidification

Dehumidification

FIGURE 2·1

SAMPLE RESIDENCY QUESTIONNAIRE

WHAT WAS THE FIRST/NEXT ADDRESS ____ LIVED AT IN PORT HOPE? (REPEAT UNTIL REACH CURRENT ADDRESS OR ADDRESS AT TIME OF DEATH.)	WHAT YEARS DID ____ LIVE THERE? (SPECIFY DATE AND # YEARS.)	DID ____ HAVE FILL PUT AROUND THE HOUSE? (FROM E.N.L.)	DID ____ MAKE ANY CHANGES TO THE HOUSE? (RENOVATIONS/ ADDITIONS)	IF YES: WERE THE BUILDING MATERIALS NEW OR RECLAIMED (FROM E.N.L.)	WAS THE HOUSE HEATED WITH COAL OIL NATURAL GAS ELECTRICITY	DID THE HOUSE HAVE FORCED AIR?	DID THE HOUSE HAVE AIR CON- DITIONING
1. Little Hope St.	19 49 TO 19 50 # YRS. 1	yes but ENL?	yes	basement possibly	wood + coal	DK	no
2. Ellen St.	19 50 TO 19 52 # YRS. 2	yes but BNL?	"	"	"	yes	"
3. Margaret	19 52 TO 19 53 # YRS. 1	now possibly	still uses old stuff - possibly	DK - possible	oil	DK	"
4. Brown St.	19 53 TO 19 53 # YRS. months	no	no	—	coal or wood	no	"
5. Ridout	19 53 TO 19 55 # YRS. 2	DK - moved in right - filled up	no	—	oil	yes	"
6. Mill St. N.	19 55 TO 19 56 # YRS. 1	yes?	yes	DK	oil	DK	"
7. Bramley St.	19 56 TO 19 57 # YRS. 1	never – lot of fill moving around at time possibly	DK - when built?	DK -	oil	yes	"
8. Ellen St.	19 57 TO 19 61 # YRS. 4½	no?	yes	DK	oil	yes	"
9. John St.	19 61 TO, 19 62 # YRS. [illegible]	no	no	—	gas	"	"
10. Princess St	19 62 TO 19 70 # YRS. 8	[illegible] possibly	no	—	"	"	"

NOTE: MAKE SURE THAT IF A MOVE AWAY FROM PORT HOPE IS INDICATED, YOU MUST FIND OUT IF THEY MOVED WITHIN DURHAM COUNTY PRIOR TO 1973, OR NORTHUMBERLAND COUNTY AFTER 1973. IF SO, GET ADDRESSES AND YEARS LIVED THERE.

Of these 380 residences, only 18 were designated by the Atomic Energy Control Board as potential radon problem homes requiring additional sampling based on the results of the 1976 investigations. Six of these 18 residences were purchased by Eldorado in 1976 and 1977 as part of the refinery expansion program and as a result did not require any additional pre-remedial radon sampling. The remaining 12 homes were investigated in some detail as part of the remedial action program discussed earlier.

2.3 Characteristics of Radon and Radon Daughter Data Set

2.3.1 Subdivision of Data

Since air samples were collected in most structures in Port Hope as part of the 1976 AECB and MOH investigations, it was initially hoped that these results could be incorporated in the dose reconstruction. Unfortunately for most of the structures, the collected air samples were only analysed for radon, with no measurement of radon daughter concentrations. In addition, usually only one sample on the main floor and one in the basement were collected per home. The validity of these measurements as a truly representative historical value for the structure is uncertain. For this reason the characteristics of the data sets noted in Table 2.1 and 2.2 were examined in the hope that a generalized radon/working level relation would evolve which would be common to most of the homes investigated.

Of the approximately 550 properties investigated as part of the remedial action program, radon and working level results for 408 properties were summarized in a computerized data base. For the purpose of this report, the complete radon/working level data base was divided into two basic categories - Radon Problem and Non-Radon Problem homes, with 124 and 284 structures in each category respectively. Initially the AECB identified 150 homes as radon problem structures and asked that they be investigated on that basis. However, this number was eventually reduced to 124 for a variety of reasons including the purchase and subsequent demolition of several radon problem homes by Eldorado Nuclear Limited as part of their plant expansion scheme.

Following this initial division into radon and non-radon homes each category was further subdivided into easily identifiable groups in an attempt to develop characteristic radon/working level values that could be easily applied to a structure meeting the necessary specifications.

The categories into which the data were divided and the number of data in each category are summarized in Table 2.3. As explained in Section 2.1, to prevent biasing the data, only pre-remedial and special request type samples were used in the analysis. These types of samples were considered to be most representative of the structure's historical radon and radon daughter levels.

Figures 2.2 and 2.3 show the cumulative frequency distributions of the pre-remedial radon and radon daughter data summarized in Table 2.3. In all cases, the frequency distribution curves for the radon problem homes lie well above the corresponding curves for the non-radon problem homes. In addition, the frequency distribution curves for non-radon problem homes with forced air heating are all below the corresponding curves for non-radon problem homes without forced air heating.

TABLE 2.3

RADON DATA BASE CHARACTERISTICS

Category	Number of Structures	Number of Measurements		
		Radon only	WL only	Both Radon &
Non Radon Problem Homes	272	2687	1702	1695
Frame	150	-	922	-
Brick	122	-	780	-
Forced Air	213	2182	1363	1358
Non Forced Air	59	505	339	337
Basement	-	1355	820	816
Non Basement	-	1332	882	879
Radon Problem Homes	123	1918	883	870
Frame	70	-	308	-
Brick	53	-	575	-
Forced Air	81	1096	592	584
Non Forced Air	42	822	291	286
Basement	-	1131	435	427
Non Basement	-	787	448	443

The effect of forced air heating on the distributions of radon and working levels in radon problem homes is most evident for non-basement locations. The frequency curve for radon levels in non-basement areas of homes without forced air heating falls below the corresponding curve for homes with forced air heating for radon concentrations above about 2-3 pCi/L. Similarly, above about 0.03 WL, the radon daughter concentrations in non-basement locations of radon-problem homes with forced air heating are higher than the radon daughter levels in radon-problem homes without forced air heating. This is presumably the result of a redistribution of radon from basement to non-basement areas via the heating system air flows. In any event, the highest radon daughter levels occur in the basements of radon-problem homes as would be expected.

In general terms, many of the cumulative frequency curves exhibit a linear tendency, particularly in non-basement areas. This is suggestive of a log-normal distribution of radon and working level data.

For comparison purposes, the Port Hope data and the results of a cross-Canada survey conducted by the Department of National Health and Welfare (McGregor et al, 1980) are shown plotted in Figure 2.4. The distribution of radon and radon daughter concentrations in Port Hope radon-problem homes is clearly elevated compared to either the Port Hope non-radon problem homes or the cross-Canada data. In addition, the cumulative frequency distribution for non-radon problem homes in Port Hope appears to exhibit radon and radon daughter levels higher than those reported in the cross-Canada survey.

2.3.2 Seasonal Variation of Data

The fluctuation of working level concentrations throughout the course of a year, within a structure, has been investigated for several areas (Scott 1979, Case 1979, Haywood 1980). Studies carried out during the remedial work programs in Port Hope and Bancroft suggest that the monthly mean equilibrium ratio between radon daughter and parent radon concentrations varies directly with ambient outdoor temperature and ranges from a winter low of 0.2 to a summer high of 0.8. Figure 2.5 shows the monthly variation of the average equilibrium factor and temperature for Port Hope (Case, 1979).

Figure 2.6 depicts the mean concentration of radon and radon daughters, and the equilibrium fraction as a function of ambient outdoor temperature for the non-radon problem homes data base. A review of this figure suggests that over the annual temperature range (-10 to +25°C) the radon concentrations remain relatively constant whereas the radon daughter concentrations and corresponding equilibrium fraction tend to increase with outdoor temperature. This is likely a result of the increased ventilation rates of the structures at lower outdoor temperature because of the increased use of heating systems. Based on these results it appears that the mean outdoor temperature could be used to predict the mean equilibrium fraction which may exist in a structure. Therefore if only radon data were available for a structure, it might be possible to predict the mean annual radon daughter concentration for that structure. However, this data also suggests that it may be incorrect to assume that one specific radon daughter measurement is truly representative of that structure's mean annual working level concentration, unless of course, the ambient outdoor temperature at the time of

FIGURE 2·2

DISTRIBUTION OF PRE-REMEDIAL WORKING LEVEL DATA — BY SAMPLING LOCATION, HEATING SYSTEM, AND STRUCTURE DESIGNATION

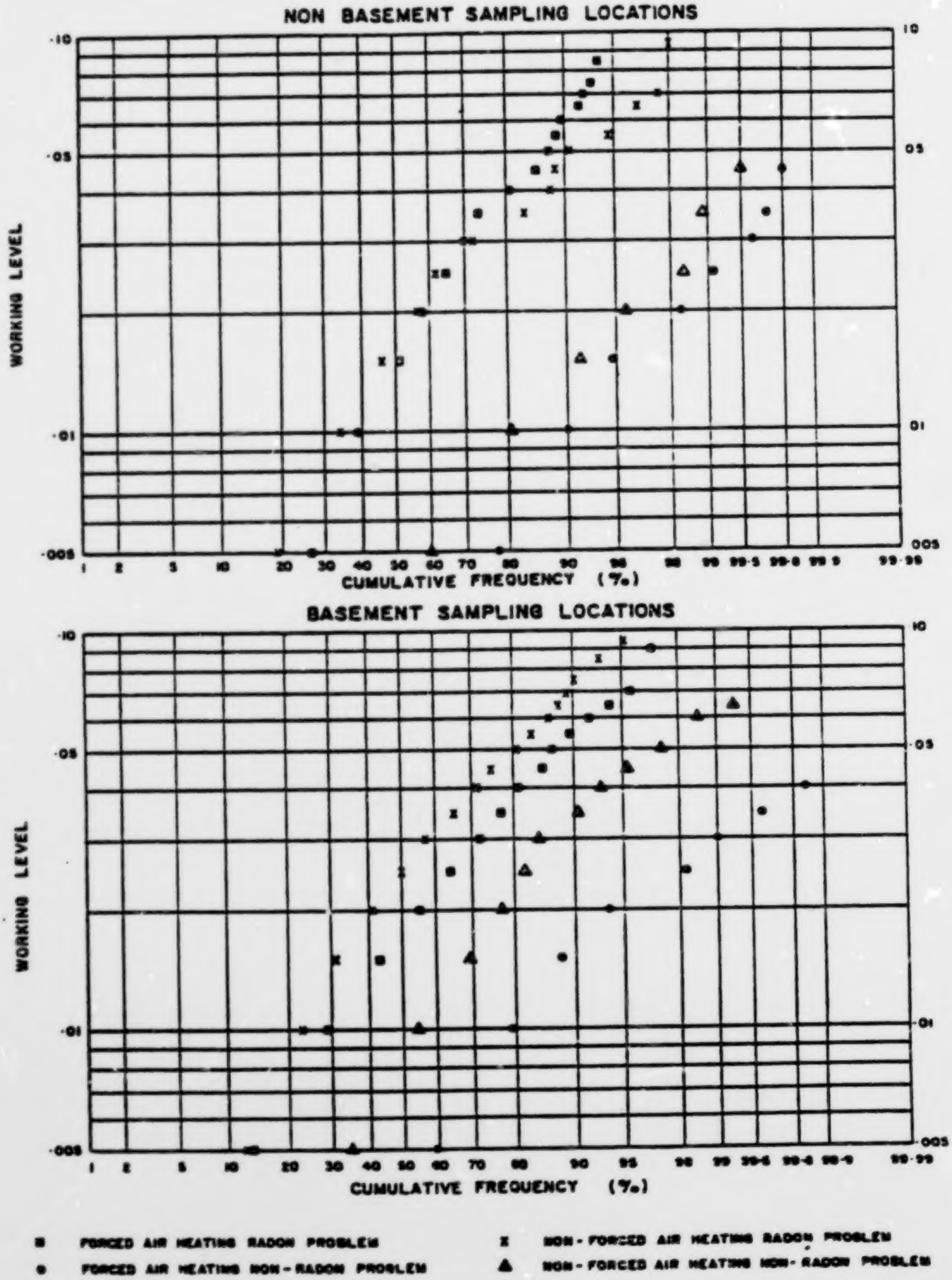
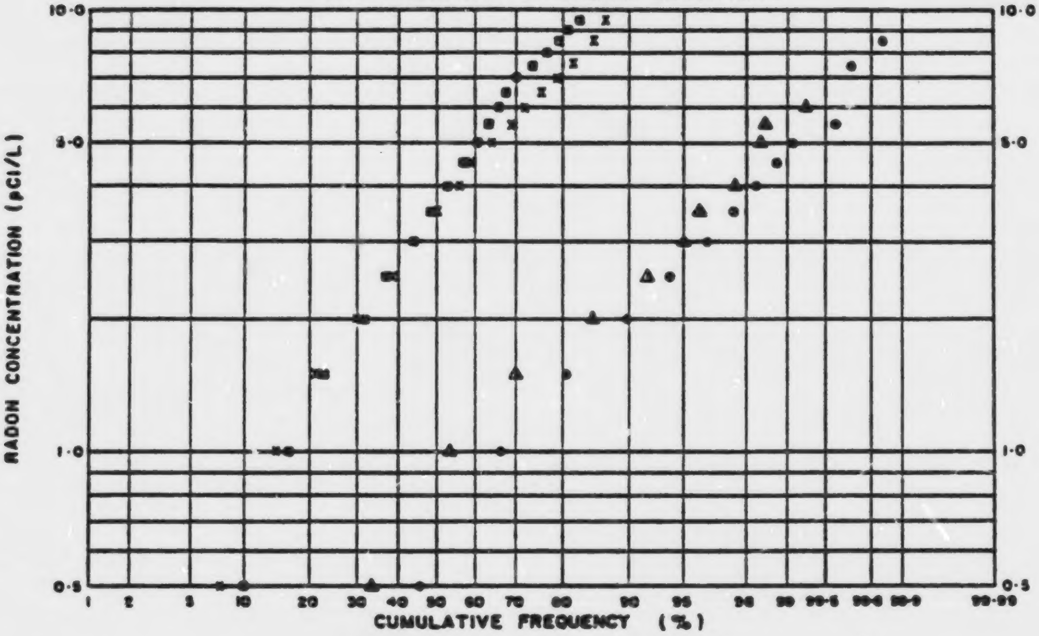


FIGURE 2-3

DISTRIBUTION OF PRE-REMEDIAL RADON DATA — BY SAMPLING LOCATION, HEATING SYSTEM, AND STRUCTURE DESIGNATION

NON BASEMENT SAMPLING LOCATIONS



BASEMENT SAMPLING LOCATIONS

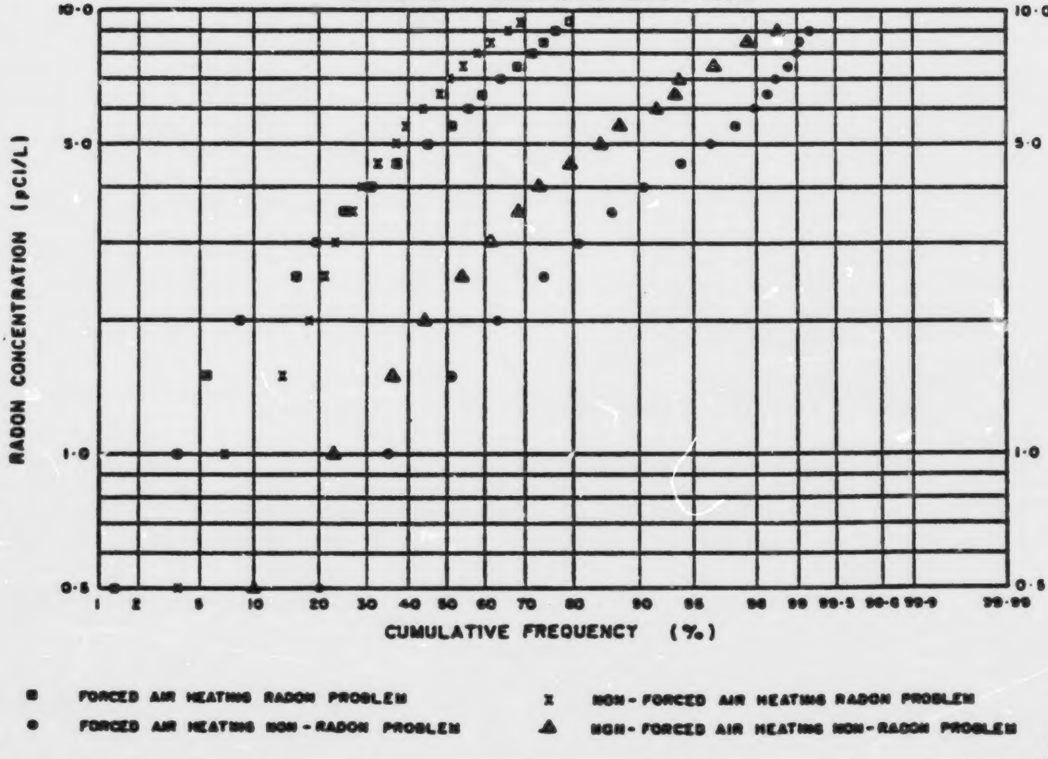


FIGURE 2.4

DISTRIBUTION OF RADON AND WORKING LEVEL DATA FOR PORT HOPE AND CROSS CANADA HOMES

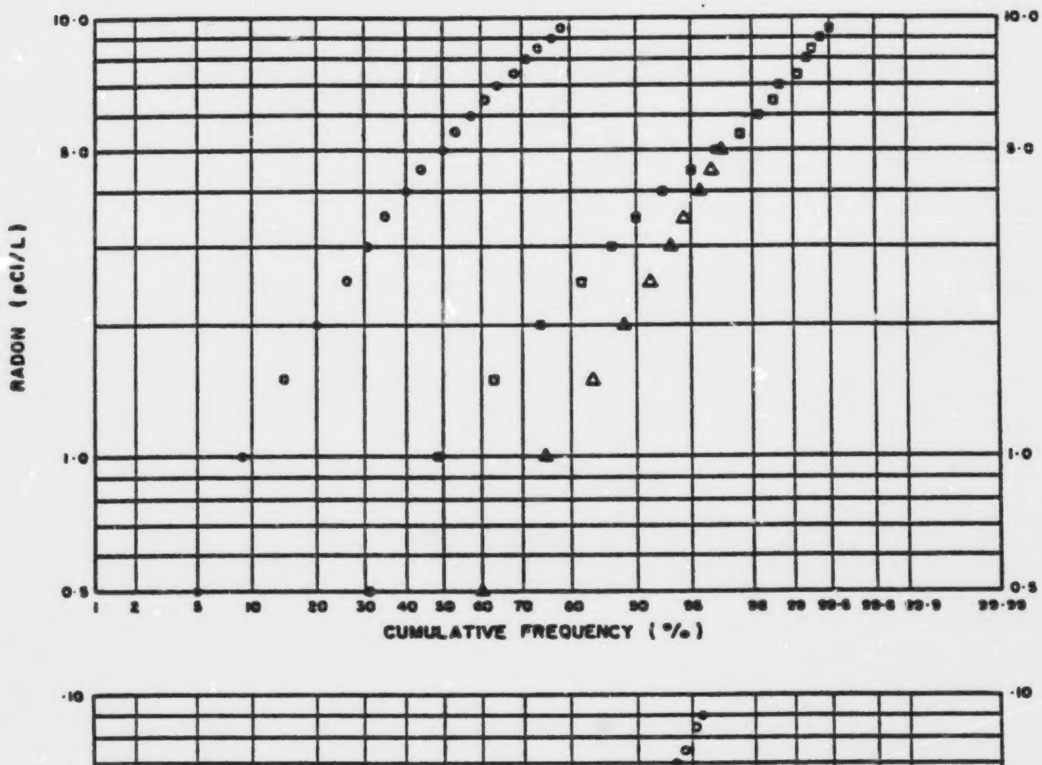
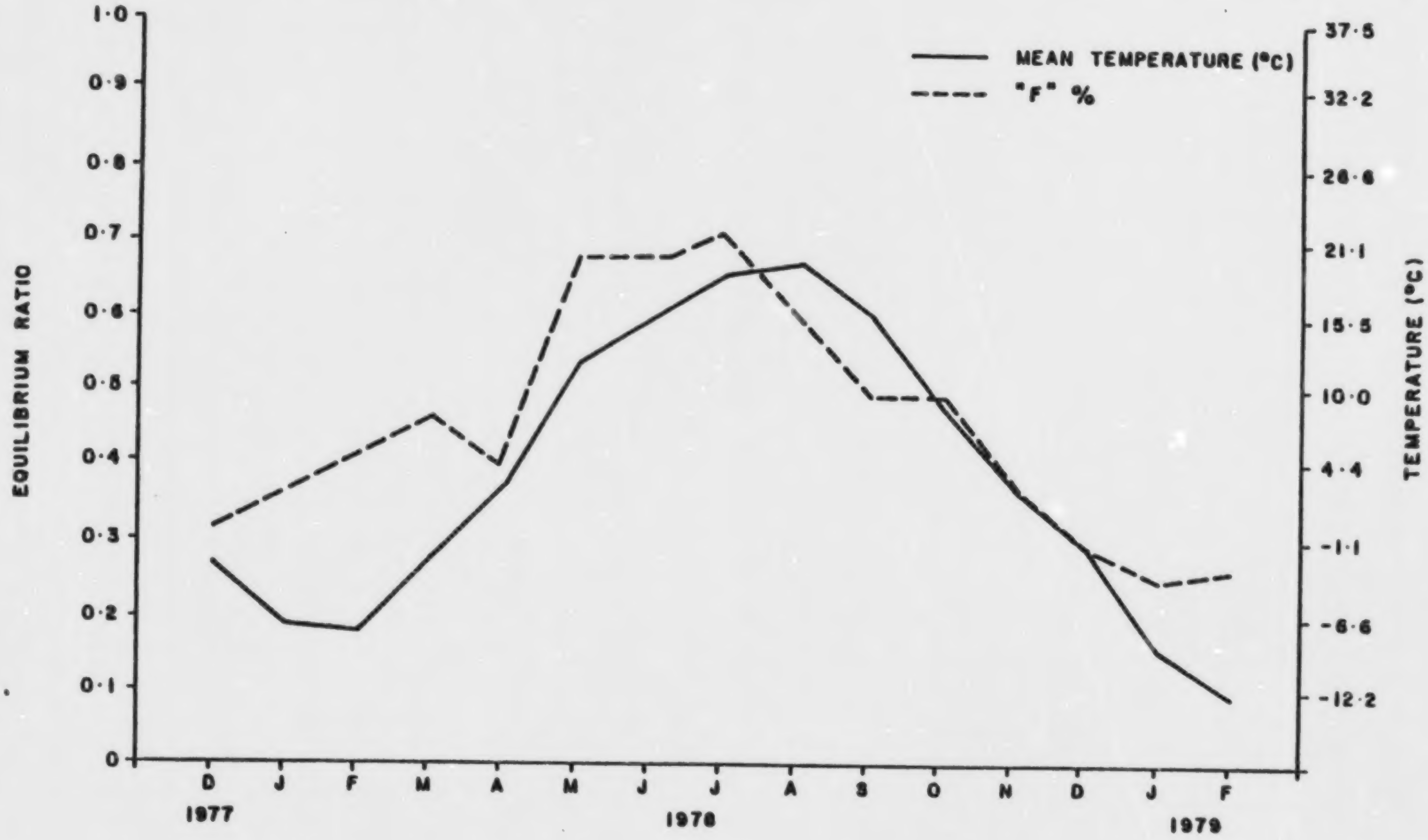


FIGURE 2·5

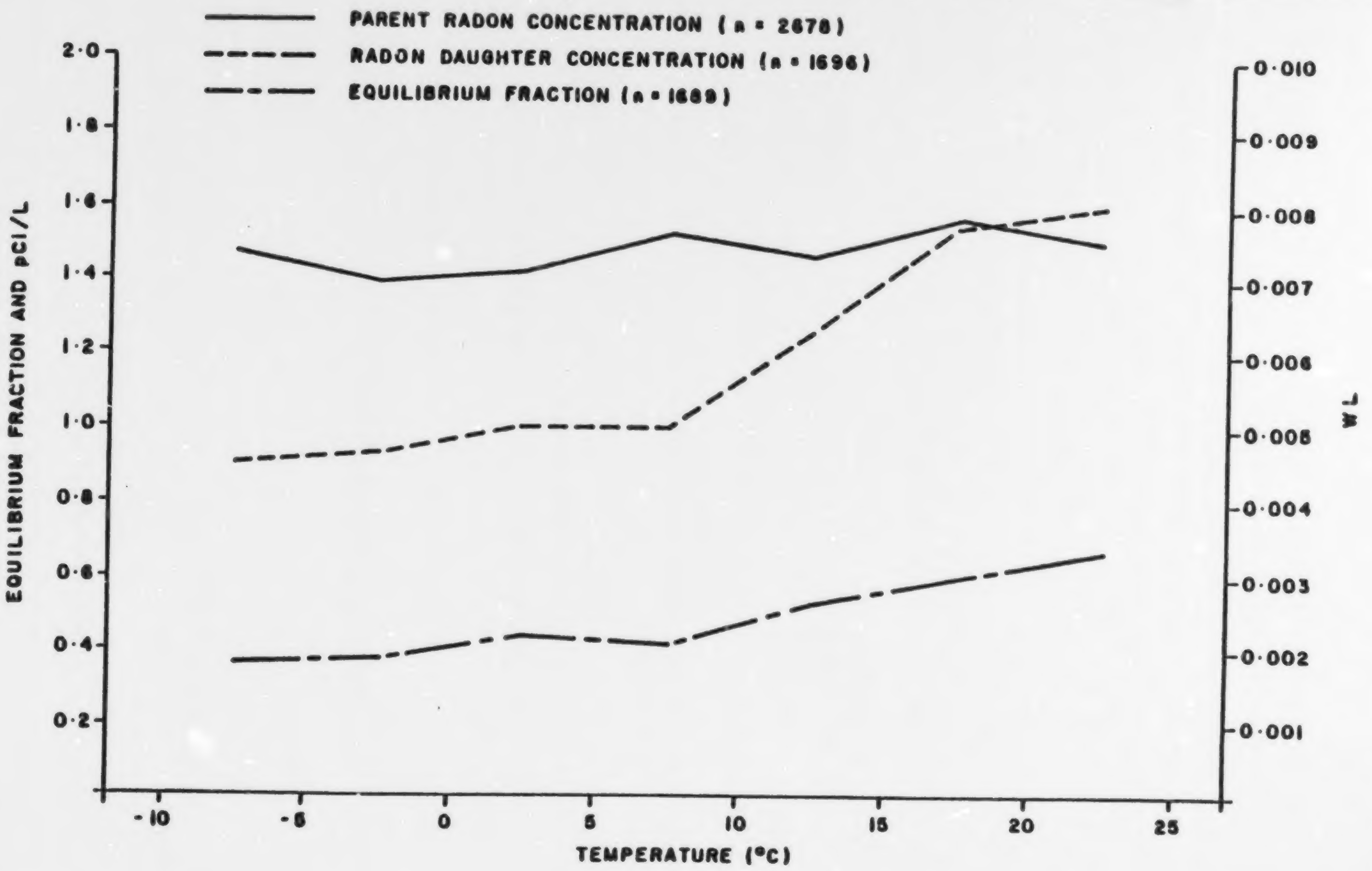
MEAN MONTHLY EQUILIBRIUM RATIO AND OUTDOOR TEMPERATURE
MEASURED IN PORT HOPE FOR THE PERIOD: DECEMBER, 1977 TO FEBRUARY, 1979



ADAPTED FROM, CASE 1979

FIGURE 2·6

MEAN CONCENTRATION OF RADON AND RADON DAUGHTERS BY TEMPERATURE FOR NON RADON PROBLEM HOMES



sampling was equal to the mean annual temperature. For this reason a correlation was developed to adjust specific working level measurements in such a manner that they could be considered representative of the mean annual working level concentration. This adjustment was based on a mean annual temperature of 6.5°C measured during the period when working level samples were collected. Table 2.4 summarizes the temperature and working level data used in these calculations. The correlations for the radon problem and non-radon problem homes are as follows:

Non-radon problem homes:

$$WL = 4.91 \times 10^{-3} + (1.29 \times 10^{-4})T \qquad r^2 = 0.79$$

Radon problem homes:

$$WL = 2.14 \times 10^{-2} + (3.77 \times 10^{-4})T \qquad r^2 = 0.89$$

Fitting the data to non-linear functions did not improve the statistical significance of the fits.

Based on these empirical correlations the following equations were used to adjust the individual working level measurements to be representative of measurements taken at the mean temperature of 6.5°C.

Non-Radon Problem Home

$$WL_A = \frac{1}{0.847 + 0.022T} \cdot WL_T$$

Radon Problem Home

$$WL_A = \frac{1}{0.892 + 0.0157T} \cdot WL_T$$

where:

T = ambient outdoor temperature (°C) at time of working level measurement

WL_T = specific working level measurement to be adjusted

WL_A = adjusted working level measurement based on mean annual Port Hope temperature of 6.5°C.

TABLE 2.4

SUMMARY OF DATA USED IN DEVELOPMENT OF WORKING LEVEL - TEMPERATURE CORRELATION

Mean Monthly Temperatures (°C) For Working Level Sampling Period

Year	J	F	M	A	M	J	J	A	S	O	N	D
1976	-	-	-	-	-	-	-	-	14.4	6.9	1.2	-6.4
1977	-	-	-	-	-	-	-	-	-	-	-	M
1978	-7.9	-7.9	-2.5	5.1	12.0	15.6	19.6	19.7	15.2	8.9	3.5	-1.5
1979	-6.2	-9.9	1.8	5.5	10.6	15.4	20.6	18.8	15.4	8.8	5.1	E
Mean	-7.05	-8.9	-0.4	5.3	11.3	15.5	20.1	19.3	15.0	8.2	3.3	-4.0

Notes:

Mean annual temperature for sampling period = 6.5°C

-: no working level samples taken during this month; M: temperature data missing; E: end of data base compilation.

Non Radon Problem Homes

Temperature Range °C	Mean WL
-10 to - 6	0.0045
- 5 to - 1	0.0046
0 to 4	0.0050
5 to 9	0.0050
10 to 14	0.0063
15 to 19	0.0077
20 to 24	0.0080

Radon Problem Homes

Temperature Range °C	Mean WL
-10 to - 6	0.020
- 5 to - 1	0.020
0 to 4	0.023
5 to 9	0.021
10 to 14	0.026
15 to 19	0.030

2.3.3 Radon Data Uncertainties

Since the purpose of this report is to estimate the total working level month exposure for an individual while living in a specific Port Hope residence, the most applicable historical data are actual working level measurements made in the particular residence in question. Unfortunately, most of the air samples collected by the government agencies during the 1976 campaign were analysed for radon only. Briefly, the sampling consisted of opening an evaluated 2-litre glass bottle to obtain a sample of room air. The bottle was then sealed and taken to a laboratory in Toronto where the sample was transferred to a counting chamber, to determine the number of picocuries of radon in a litre of the original room air.

Because of the very low levels encountered, a series of samples should have been taken in each structure to establish the range of radon concentrations, however, time constraints only allowed this multiple sampling on a selective basis. As a result most homes were only sampled once, and in the context of this report the validity of this single value as representative of historical levels (up to 40 years prior) in the home is very questionable. Therefore, to minimize the degree of uncertainty, individual values measured in non-radon problem homes were not used, but were instead replaced with generalized values based on structure type as developed from the data base. Based on the information provided by the Queens questionnaire, each non-radon problem home was characterized and the appropriate exposure estimate selected. The use of the generalized data is explained in Section 3.2.

3.0 APPROACH TO DOSE RECONSTRUCTION

3.1 General

The dose reconstruction for the cases and controls identified in the main epidemiological study required the consideration of several factors prior to the actual assignment of a total working level month value. These factors generally fell into two major categories, namely those relating to the case or control and those relating to the residence(s) occupied by the case or control during the period in question.

For the actual dose reconstructions the case/control factors (such as period of residence, work history including location and duration) were applied to an annual potential exposure value developed using the specific residence factors (such as building type, heating system type, total useage potential, age, location), identified during the in-field interviews. The resultant annual exposures were then summed for the required number of years to reconstruct the total estimated dosage. A discussion of this logic plan is included in Section 3.2 while the data characteristics used in the development of the logic plan are included in Section 3.3.

3.2 Logic Plan for Dose Reconstruction

As discussed in Section 3.1, the approach to the dose reconstruction was to estimate the potential exposure for each year, based on specific resident information; correct this potential exposure to reflect the amount of time that the individual was actually in the residence; and sum the corrected annual exposures for the period of exposure specified by Queens University.

To ensure an unbiased estimate of exposure, the data for the individuals in the study were supplied by Queens in a blind fashion with reference only to an identification number. The information supplied under the identification number included the sex of the individual, the year ending the exposure period, the individual's work history while a resident of Port Hope, and addresses and specific information for each of the Port Hope homes occupied by the individuals. A sample residence information sheet is shown on Figure 2.1.

Figure 3.1 outlines the logic plan used in the preparation of the exposure estimates. Explanations of the individual steps are discussed below.

Identification Number for Case/Control

As discussed previously the data were supplied by Queens in a blind fashion, so an identification numbering system was adopted. The 118 cases/controls were individually numbered from 1 to 117 with the exception of 107A and 107B.

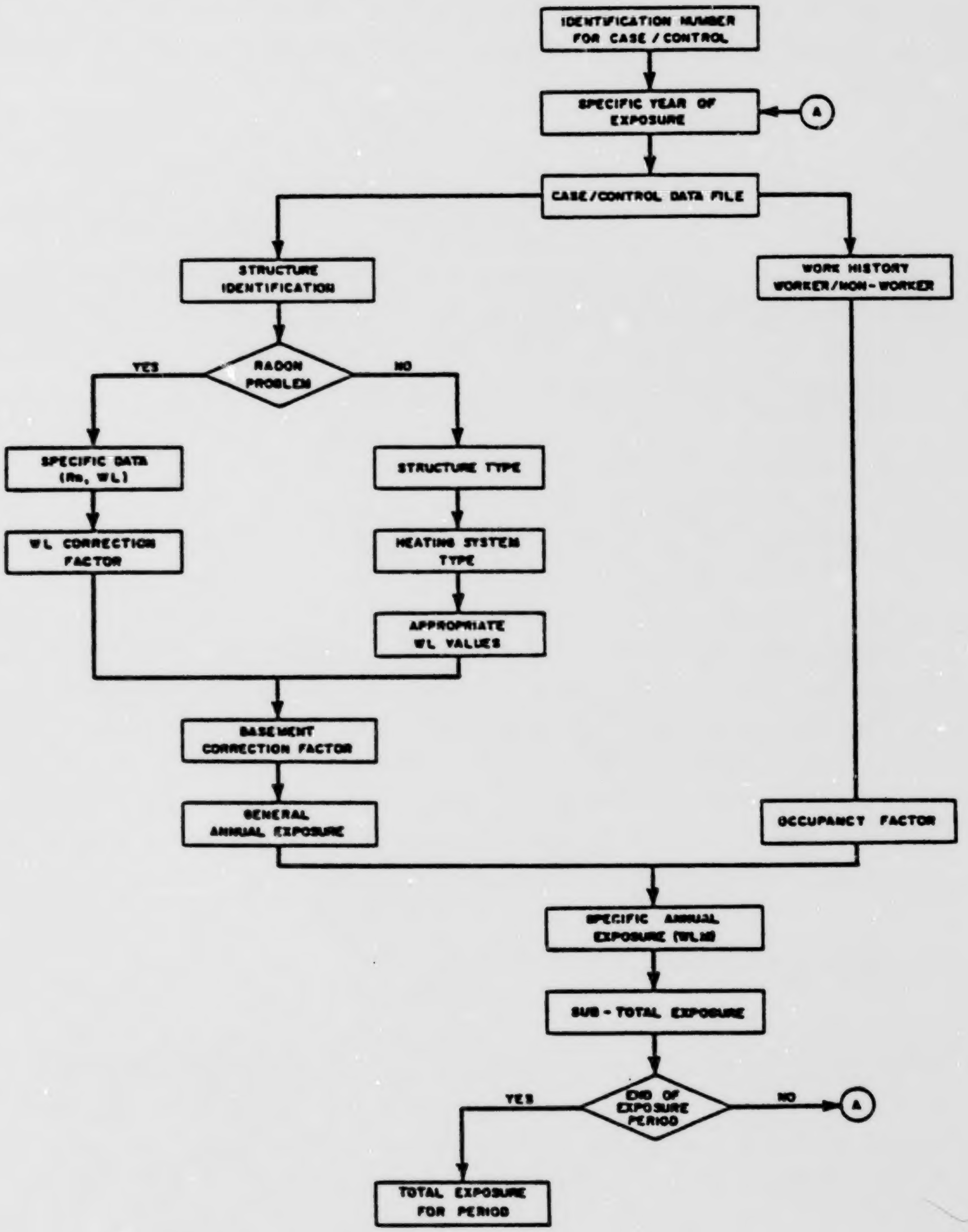
Specific Year of Exposure

This block is the starting point for the individual annual exposure estimates and is a critical point in the logic plan.

The final year of exposure was specified by Queens, however the initial year of exposure was dependent upon when the individual became a resident of Port Hope. For lifetime residents, only exposures for the period after 1933 (start of refining operations) were estimated. For individuals moving to Port Hope after 1933 the initial year of residence was considered the initial year of exposure. Initial years

FIGURE 3-1

LOGIC PLAN FOR DOSE RECONSTRUCTION


IDENTIFICATION NUMBER FOR CASE / CONTROL
SPECIFIC YEAR OF EXPOSURE
A
CASE/CONTROL DATA FILE
STRUCTURE IDENTIFICATION
WORK HISTORY WORKER/NON-WORKER
RADON PROBLEM
YES
NO
SPECIFIC DATA (Rn, WL)
STRUCTURE TYPE
WL CORRECTION FACTOR
HEATING SYSTEM TYPE
APPROPRIATE WL VALUES
BASEMENT CORRECTION FACTOR
GENERAL ANNUAL EXPOSURE
OCCUPANCY FACTOR
SPECIFIC ANNUAL EXPOSURE (WLM)
SUB - TOTAL EXPOSURE
END OF EXPOSURE PERIOD
YES
NO
A
TOTAL EXPOSURE FOR PERIOD

of exposure ranged from 1933 to 1969 while final years of exposure ranged from 1969 to 1981. The mean total exposure period was 31 years and ranged from a low of 7 to a high of 48 years of residence in Port Hope.

Case/Control Data File

This block contains all the information obtained through the in-field interviews conducted by Queens. The two outputs from this block, structure identification and work history, were the starting points for the development of the general annual exposure estimate and the occupancy factor.

Work History/Occupancy Factor

Following a review of the work history for the specific year under consideration, the individual was classified as either a worker or a non-worker. For the worker, it was assumed that the individual spent an average of 60 percent of the entire year actually inside the home. For the non-worker, (e.g. housewife) it was assumed that the individual spent an average of 85 percent of the entire year actually inside the home. Retired persons and individuals whose work address was the same as that for their residence were also assigned the 85 percent occupancy factor.

Structure Identification/Radon Problem

Following the application of a specific year to the case/control data file, the address of the appropriate residence was identified. The address was compared with the list of radon problem homes designated by the AECB as part of the 1976 survey. If the structure was designated as a radon problem home then data for the specific structure was selected. If, on the other hand, the structure was identified as a non-radon problem home, then the general characteristics of the data for the appropriate structure type and heating type were selected. A detailed description of the characteristics of the generalized data sets appears in Section 3.3.

For the 118 case/control investigations, a total of some 356 homes were identified, of which 14 were classified as radon problems. The greatest number of addresses identified for two particular individuals was 11, over 25 and 38 year periods.

Radon Problem/Specific Data/WL Correction Factor

If the structure was identified as a radon problem home, specific working level and radon data were compiled from the data files, and corrected using the factors discussed in Section 2.3.2. The resultant average radon daughter concentration was then incorporated in the following expression to obtain the potential annual exposure in Working Level Months (WLM).

$$\begin{aligned}\text{Potential Annual Exposure (WLM)} &= \text{Average Radon Daughter Concentration (WL)} \\ &\quad \times \frac{24\text{ hours}}{\text{day}} \times \frac{365\text{ days}}{\text{year}} \times \frac{1\text{ month}}{168\text{ hours}} \qquad (3\text{-}1) \\ &= \text{Average Radon Daughter Concentration} \times 52.14\end{aligned}$$

It should be noted that this conversion of radon daughter concentration (in WL's) to annual exposure (in WLM's) is strictly based on the definition of the working level month, a limit originally derived for measuring the exposure of uranium miners (Evans, 1979). It has been noted by others (e.g. Guimond et al, 1978) that the cumulative exposures for a given concentration of radon daughters differs between miners and the general public because of different breathing rates. It has been suggested that an annual exposure to 1 WL corresponds to 27 WLM for exposures occurring in the general environment. However, this is not strictly correct because of the definition of the WLM, which is independent of breathing rate and related physiological factors. While it is realized that the potential dose to the lung may depend on how the exposure to radon daughters is accumulated (Evans et al, 1982) and that such factors should be included in any discussion of the results of epidemiological studies, the strict definition of WLM should not be altered.

An example of data for one such radon problem home, requiring application of the WL correction factor, follows:

Sample Location	Ambient Outdoor Temperature (°C)	Measured WL		Corrected WL*
Main Floor	-8	0.041		0.053
Main Floor	-7	0.040		0.051
			mean	0.052
Basement	-8	0.058		0.076
Basement	-7	0.050		0.064
Basement	-10	0.068		0.093
Basement	-10	0.050		0.082
Basement	-10	0.050		0.068
			mean	0.077

*measured Working Level corrected using temperature correlation (Section 2.3.2).

Main floor, potential annual exposure = 0.052 WL x 52.14
= 2.7 WLM

Basement, potential annual exposure = 0.077 WL x 52.14
= 4.0 WLM

Structure Type/Heating System Type/Appropriate WL Values

The available data were characterized in terms of these parameters since it was considered they would probably have the greatest effect on the measurements. If the structure was identified as a non-radon problem home, then the generalized data approach, incorporated in these three blocks in Figure 3.1, was applied. Under structure type, the residence was reviewed in terms of age and type (i.e. apartment, duplex, detached, etc.). This information was required in the selection of the appropriate basement correction factor, discussed later.

The interview data included the heating system type during the period when the residence was occupied. The heating systems were classified as either forced air or non-forced air. The non-forced air category included such heating systems as electric baseboard, oil or gas-fired hot water, space heating, wood stove, gravity oil or coal-fired, etc. The forced air category, as the name implied, included all systems where the heated air in the home was forced throughout the residence by mechanical fan action. The three forced-air systems were either electric, oil or gas-fired. Based on the type of heating system in use for the specific year, the appropriate annual working level value was selected. The four possible values are summarized in Table 3.1 and are discussed in Section 3.3.

TABLE 3.1

GENERALIZED POTENTIAL ANNUAL EXPOSURE FOR NON-RADON PROBLEM HOMES (WLM)

Location	Forced Air	Non-Forced Air
Main Floor (non-basement)	0.224	0.318
Basement	0.339	0.720

Basement Correction Factor/General Annual Exposure

Since a measurable difference in radon daughter concentrations exists between basement and non-basement locations, a basement correction factor was developed to take account of the relative contribution of two locations in the overall general annual exposure estimate. The three factors, designated as B_0, B_1, B_4, were based on the potential number of hours spent in the basement location on a daily basis (0, 1 and 4 hours respectively). Newer homes with recreation and family rooms in the basement were assigned a B_4 rating, whereas older homes with limited access basements were assigned B_0 or B_1 ratings. Apartments and hotel rooms were assigned B_0 ratings.

The assignment of an appropriate basement correction factor was based on information obtained through the in-field interviews and in some cases actual inspection of the residence.

The general annual exposures estimated for the non-radon problem homes are summarized in Table 3.2.

TABLE 3.2

GENERAL ANNUAL EXPOSURE ESTIMATES FOR NON-RADON PROBLEM HOMES (WLM)

Heating System Type	Basement Classification		
	B_0	B_1	B_4
Forced Air	0.224	0.229	0.243
Non-Forced Air	0.318	0.335	0.385

The radon problem home example discussed earlier, was assigned a B_4 correction value resulting in the following general annual exposure estimate:

$$\text{General annual exposure} = \frac{4}{24}\begin{pmatrix}\text{Basement Potential}\\ \text{Exposure}\end{pmatrix} + \frac{20}{24}\begin{pmatrix}\text{Main Floor Potential}\\ \text{Exposure}\end{pmatrix}$$

$$= 0.17\ (4.0\ \text{WLM}) + 0.83\ (2.7\ \text{WLM})$$

$$= 2.92\ \text{WLM}$$

Specific Annual Exposure (WLM)

To obtain the specific annual exposure for the year in question, the general annual exposure estimate was multiplied by the appropriate occupancy factor. The appropriate occupancy factors used for workers and non-workers were 0.6 and 0.85 respectively as discussed previously.

Sub-Total Exposure/End of Exposure Period/Total Exposure for Period

The total exposure for the period was arrived at by summing the specific annual exposures for each year included in the exposure period. For most individuals the exposure period was continuous; however, the exposure periods for 14 individuals were interrupted for periods ranging from one to 21 years as a result of wartime service or relocation to another centre outside Port Hope.

3.3 Summary of Data Characteristics

As discussed in Section 3.2, exposures in non-radon problem homes were estimated using general characteristics of the data. These characteristics were based on the results of the radon and radon daughter sampling carried out as part of the Port Hope remedial action program. Some 1700 pre-remedial working level samples were collected in non-radon problem homes with forced or non-forced air heating systems. In addition to the working level samples, 2687 radon samples were collected. Simultaneous radon and radon daughter sampling resulted in 1695 equilibrium fractions. These data are summarized on Table 3.3. Table 3.4 summarizes a similar set of data for radon problem homes. Arithmetic mean values are presented in these tables for historical reasons although it is recognized that geometric mean values may provide a better description of the data.

The mean working level values for the non-radon problem homes were used to establish the generalized annual total potential exposures for the four standard conditions namely forced air basement, forced air non-basement, non-forced air based and non-forced air non-basement. The values were derived in the same manner described in Section 3.2 - Radon Problem-Specific Data/WL Correction Factor, and are summarized on Table 3.5.

TABLE 3.5

NON-RADON PROBLEM HOMES - POTENTIAL ANNUAL EXPOSURE

	Mean Working Level	Potential Annual Exposure (WLM)
Forced Air		
Basement	0.0065	0.339
Non-Basement	0.0043	0.224
Non-Forced Air		
Basement	0.0138	0.720
Non-Basement	0.0061	0.318

TABLE 3.3

DATA CHARACTERISTICS FOR NON-RADON PROBLEM HOMES

	Number of Samples	Arithmetic Mean	Standard Deviation
Forced Air Heating System			
Radon (pCi/L)			
- basement location	1124	1.85	1.71
- non-basement location	1058	0.92	0.99
Working Level			
- basement location	672	0.0065	0.0063
- non-basement location	691	0.0043	0.0050
Equilibrium Factor			
- basement location	669	0.44	0.33
- non-basement location	689	0.56	0.38
Non-Forced Air Heating System			
Radon (pCi/L)			
- basement location	231	2.84	2.34
- non-basement location	274	1.14	1.04
Working Level			
- basement location	148	0.0138	0.0142
- non-basement location	191	0.0061	0.0069
Equilibrium Factor			
- basement location	147	0.456	0.239
- non-basement location	190	0.557	0.314

TABLE 3.4

DATA CHARACTERISTICS FOR RADON PROBLEM HOMES

	Number of Samples	Arithmetic Mean	Standard Deviation
Forced Air Heating System			
Radon (pCi/L)			
- basement location	616	8.34	17.63
- non-basement location	480	5.07	4.57
Working Level			
- basement location	290	0.0263	0.0334
- non-basement location	302	0.0247	0.0287
Equilibrium Factor			
- basement location	285	0.399	0.23
- non-basement location	299	0.503	0.44
Non-Forced Air Heating System			
Radon (pCi/L)			
- basement location	515	8.50	9.33
- non-basement location	307	4.82	4.96
Working Level			
- basement location	145	0.0318	0.0276
- non-basement location	146	0.0233	0.0275
Equilibrium Factor			
- basement location	142	0.47	0.22
- non-basement location	144	0.52	0.21

For the radon problem homes where only specific radon data were available, the mean equilibrium fraction values, listed in Table 3.4, were used to determine the annual average radon daughter concentrations. An example of this application appears on Table 3.6.

TABLE 3.6
RADON PROBLEM HOME - EXAMPLE EXPOSURE ESTIMATE

Sample Location	Measured Radon Concentration (pCi/L)	Mean Equilibrium Fraction	Annual Radon Daughter Concentration (WL)
Basement	6.4	0.399	0.026
Basement	6.7	0.399	0.027
Basement	8.9	0.399	0.036
Main Floor	3.0	0.503	0.015
Main Floor	2.5	0.503	0.013
Main Floor	2.8	0.503	0.014

3.4 Effect of Latent Period

The exposures estimated in this study are the total exposures accumulated by the various cases and controls throughout their residency in Port Hope. However, the time lag between irradiation and the appearance of a detectable cancer (latent period) can be quite long.

Estimates of the duration of latent periods are uncertain and reported values range widely. An epidemiology study of Colorado Plateau uranium miners examined the question of exposure-time-response for risk of lung cancer following exposure to radon daughters (Lundin et al, 1971). These authors evaluated median latent periods of 5, 10, and 15 years and concluded that the ten-year latent period provided the best fit to their data.

The recent BEIR III report (1982) summarizes much of the available human data on exposure to ionizing radiation and lung cancer. Latent periods reported for mining populations in the BEIR III report range from about 10 years for U.S. uranium miners to more than twenty years for Newfoundland fluorspar miners and Swedish metal miners.

Uncertainty concerning the latent period or time-response function can be an important factor in mortality comparisons among study groups. This is particularly the situation where exposed populations are studied for a limited time period rather than to the extinction of the entire study group.

Recognizing the potential significance of latent period on any possible association between exposure and risk, the exposures for all cases and controls in this study were assessed for three latent periods: 5, 10, and 15 years. While it is possible that the actual latent period might be longer than 15 years, the use of these three latent periods were thought to be reasonable for the present study.

[illegible]

4.0 RESULTS

4.1 General

The specific results of the dose reconstruction estimates for each of the 118 cases/controls identified by Queens, are summarized in Appendix A. The information includes, for each identification number, the final year of exposure, the residences occupied during the period of exposure, the predicted annual exposure (WLM), the specific years of exposure and the corresponding occupancy factors, and the total estimated exposure for latency periods of 0, 5, 10, and 15 years.

4.2 Summary

Total exposure estimates for the 118 cases/controls range from a low of 1 WLM to a high of 172 WLM, with corresponding exposure periods of 7 and 43 years respectively. The lowest, highest and median exposure values with the corresponding number of cases/controls are summarized for each of the four latency periods in Table 4.1.

The distribution of the results for the 0 latency option, as shown on Figure 4.1 and 4.2, indicates that about 90 percent of the estimated cumulative exposures are less than 10 WLM.

Figure 4.1 suggests a geometric distribution about a median value of approximately 5.5 WLM for the 0 latency situation.

TABLE 4.1

EXPOSURE ESTIMATE SUMMARY STATISTICS

Latency Period (Years)	Number of Cases/ Controls	ESTIMATED EXPOSURES (WLM)		
		Geometric Mean	Lowest	Highest
0	118	5.52	0.96	172
5	118	4.26	0.28	150
10	113	3.50	0.27	130
15	103	3.08	0.19	104

While 4.1 exhibits a median value of about 5.5 WL for the 0 latency option, it also suggests that the exposure frequency curve may be multi-modal with clusters occurring around 3, 5.5 and beyond 10-15 WLM. The cumulative frequency distribution of exposures shown in Figure 4.2 clearly shows a discontinuity for cumulative exposures above about 10 WLM. Mean exposures for the 5, 10 and 15 year latency periods are 4.3, 3.5, and 3.1 respectively. The decrease in cumulative exposures is accentuated by the loss of 15 cases/controls between the 0 and 15 year latency periods.

4.3 Confounding Effects

There are a number or confounding effects which should be recognized as part of a case control study such as this. They are listed below with no discussion.

- incorrect exposure classification
- limited radon and radon daughter data base
- variation of exposure due to:
  - building modifications
  - heating system changes
  - uncertainty as to period of exposure
- medical irradiation
- environmental radiation exposure elsewhere
- exposure at work
- effect of smoking
- effect of exposure to other environmental carcinogens (excluding radiation and cigarette smoke).

Any one or all of the above factors may contribute to the uncertainties in the overall dose reconstruction. In view of these uncertainties and the limitations in the dose reconstruction procedures discussed in previous sections, the estimated doses must be recognized as being subject to substantial error and used with caution.

REFERENCES

BEIR III, 1980. "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980", Committee on the Biological Effects of Ionizing Radiations, Division of Medical Sciences, Assembly of Life Sciences, National Research Council, Washington, D.C., 1980.

Case, G.G., 1979. "The Seasonal Fluctuation of the Radon Daughter to Parent Radon Ratio (commonly known as the Equilibrium Factor 'f')", Presented to the Second Workshop on Radon and Radon Daughters In Urban Communities Associated with Uranium Mining and Processing, Bancroft, Ontario, March 1979.

Evans, R.D., 1969. "Engineers's Guide to the Elementary Behaviour of Radon Daughters", Health Physics, Vol. 17, pp 229-252.

Evans, R.D. et al, 1981. "Estimate of Risk from Environmental Exposure to Radon-222 and Its Decay Products", Nature, Vol. 290, 12 March 1981.

Guimond, R.J. et al, 1979. "Indoor Radiation Exposure Due to Radium-226 in Florida Phosphate Lands", EPA 520/4-78-013, February 1979.

Haywood, L.R., 1980. "Seasonal Variations in 'f' Factor", Presented in Draft Form at the Third Workshop on Radon and Radon Daughters in Urban Communities Associated with Uranium Mining and Processing, Port Hope, Ontario, March 1980.

Lundin, F.E. et al, 1971. "Radon Daughter Exposure and Respiratory Cancer Quantitative and Temporal Aspects", Report from the Epidemiological Study of United States Uranium Miners, U.S. Dept. Health, Education and Welfare, 1971.

MacLaren, James F., 1976. "The Preliminary Investigation of the Technical and Economic Factors for the First Stage Remedial Measures at Port Hope", April 1976.

SENES Consultants Limited, 1981. "Report on Environmental Data for a Health Study of Port Hope - A Feasibility Program", to Joint Committee for Health Study at Port Hope, Public Health Branch, Department of Health, January 1981.

REFERENCES (continued)

Scott, A., 1979. "Comment by A. Scott on Seasonal Fluctuation in Equilibrium Fraction", Presented to Second Workshop on Radon and Radon Daughters in Urban Communities Associated with Uranium Mining and Processing, Brancroft, Ontario, March 1979.

FIGURE 4·1

DISTRIBUTION OF EXPOSURE ESTIMATES FOR ZERO LATENCY OPTION

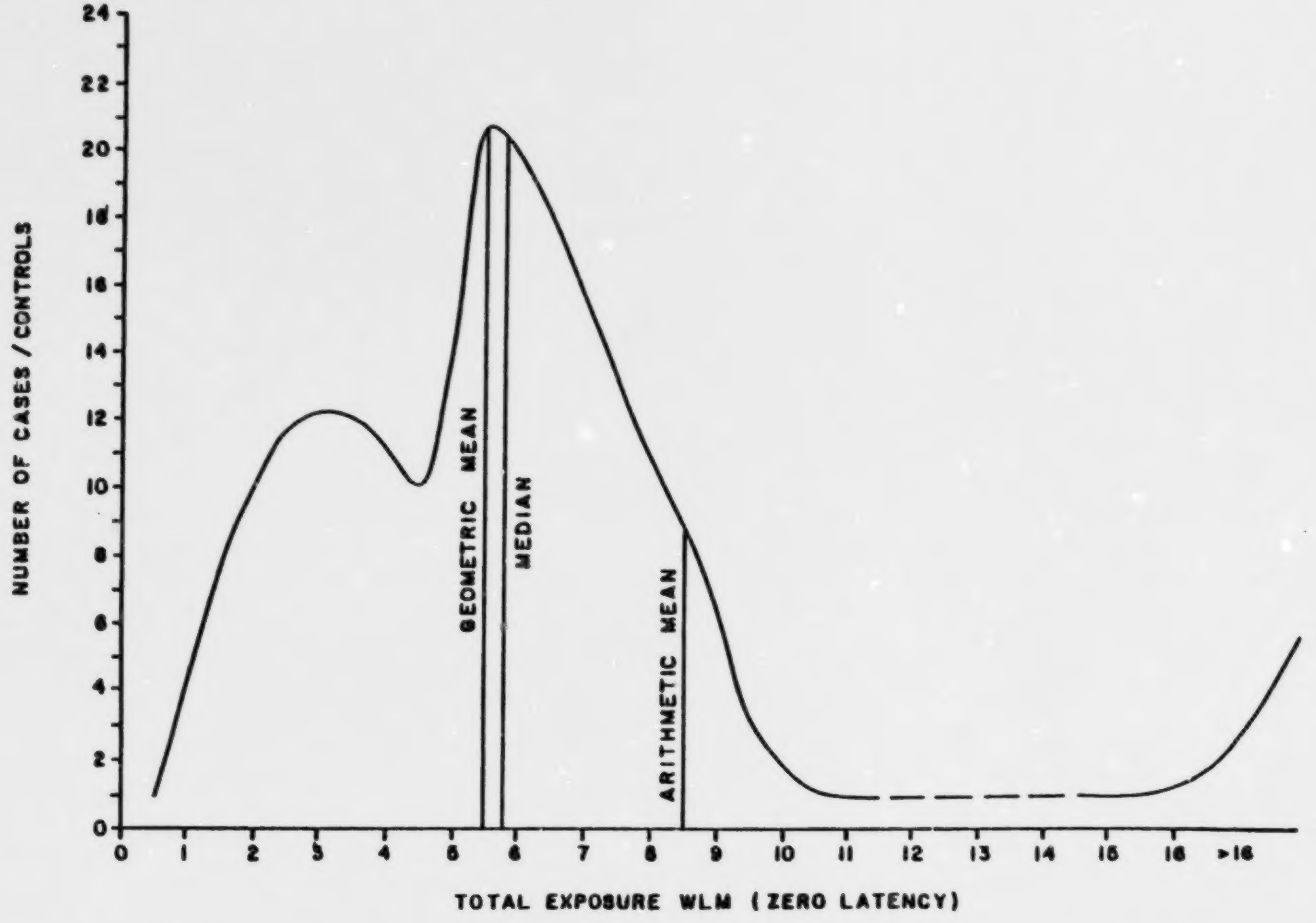
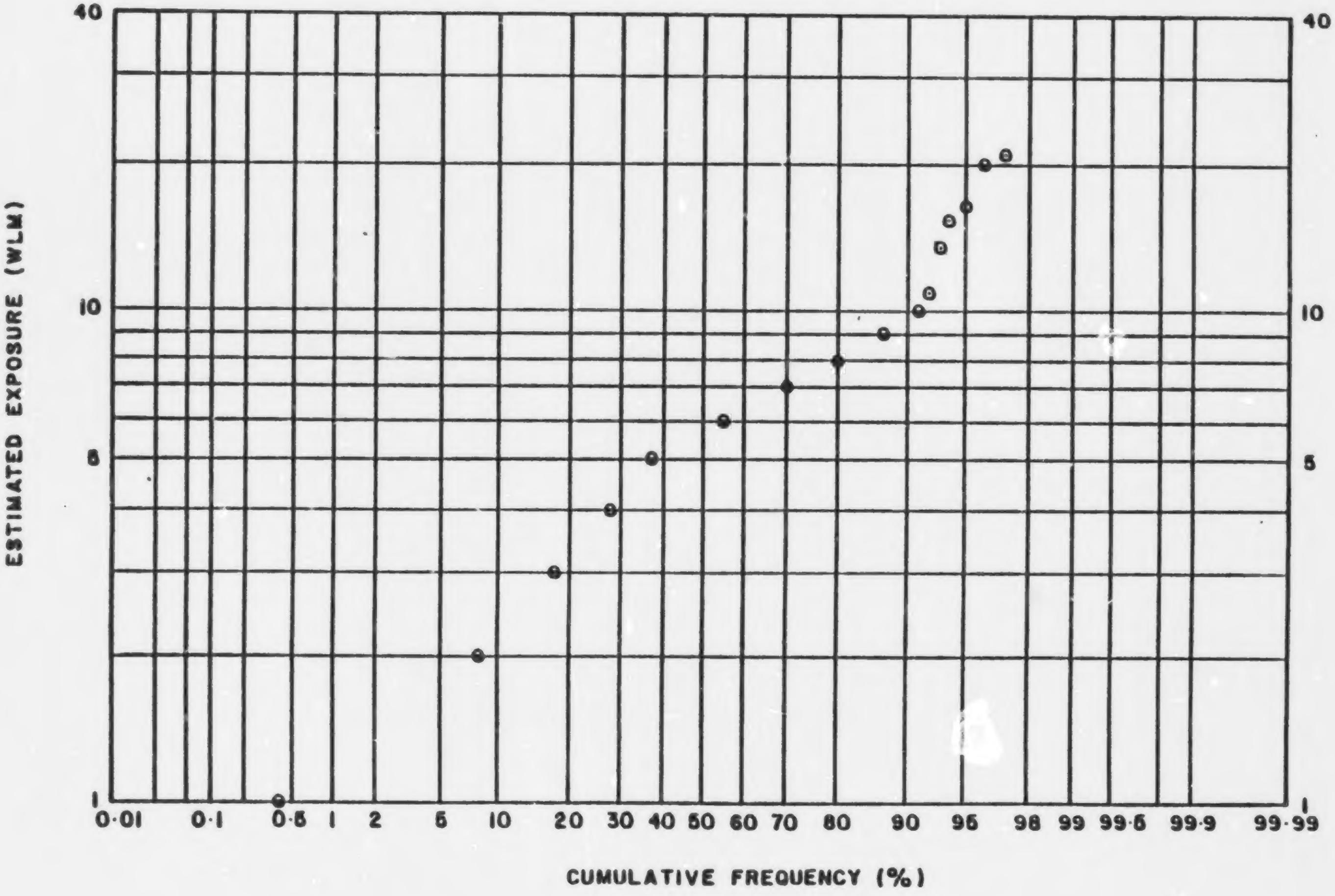


FIGURE 4·2

CUMULATIVE FREQUENCY DISTRIBUTION OF
EXPOSURE ESTIMATES FOR ZERO LATENCY OPTION



EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 1 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.) 0 Latency	5 yr	10 yr	15 yr	Comments
1	1972	73 Mill South	.417	51 - 54	3	.6	.75	.75	.75	.75	
		18 Walton	.318	54 - 56	2	.6	.38	.38	.38	.38	
		25 Bedford	.335	56 - 58	2	.6	.40	.40	.40	.20	
		59 Ellen	.229	58 - 61	3	.6	.41	.41	.41	-	
		23 Bloomsgrove	.229	61 - 72	11	.6	1.51	.82	.229	-	
		TOTAL			21		3.45	2.76	2.17	1.33	
2	1980	119 King	.318	37 - 44	7	.6	1.34	1.34	1.34	1.34	
		23 Queen	.318	45 - 46	1	.6	.19	.19	.19	.19	
		14 Caldwell	.678	47 - 70	23	.6	9.36	9.36	9.36	7.32	
		14 Caldwell	.678	70 - 80	10	.85	5.76	2.88	-	-	
		TOTAL			41		16.65	13.77	10.89	8.85	
3	1976	294 Ridout	.229	33 - 37	4	.6	.55	.55	.55	.55	
		2 Bramley North	.335	37 - 42	5	.6	1.01	1.01	1.01	1.01	lapse 1943
		5 Armour	.229	44 - 46	2	.6	.27	.27	.27	.27	
		83 Croft	.243	46 - 70	30	.6	4.37	3.65	2.92	2.19	
		TOTAL			41		6.20	5.48	4.75	4.02	
4	1978	Princess	.335	38 - 39	1	.85	.28	.28	.28	.28	
		Alexander	.335	39 - 40	1	.6	.20	.20	.20	.20	lapse 1941-42
		1 Walton	.318	43 - 46	3	.6	.57	.57	.57	.57	
		23 Caroline	.335	47 - 50	3	.6	.60	.60	.60	.60	
		159 Ontario	.243	50 - 58	8	.6	1.17	1.17	1.17	1.17	
		49 Molson	.243	58 - 66	8	.6	1.17	1.17	1.17	.73	
		Park Villa Apts.	.318	66 - 71	5	.6	.95	.95	.38	-	
		14 Shortt	.243	71 - 78	7	.6	1.02	.29	-	-	
		TOTAL			36		5.96	5.23	4.37	3.55	

EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 2 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.) 0 Latency	5 yr	10 yr	15 yr	Comments
5	1979	77 Charles	.318	33 - 41	8	.6	1.53	1.53	1.53	1.53	
		9 Little Hope	.318	41 - 42	1	.6	.19	.19	.19	.19	lapse 1943-4
		8 Bramley North	.318	45 - 46	1	.6	.19	.19	.19	.19	
		15 Bramley North	.229	46 - 79	33	.6	4.53	3.85	3.16	2.47	
		TOTAL			43		6.44	5.76	5.07	4.38	
6	1968	Strachan	.335	33 - 35	2	.6	.40	.40	.40	.04	
		1 Armour	.335	35 - 40	5	.6	1.01	1.01	1.01	1.01	
		74 Hope South	.229	40 - 68	28	.6	3.85	3.16	2.47	1.79	
		TOTAL			35		5.26	4.57	3.88	3.20	
7	1978	Dorset West	.335	44 - 50	6	.85	1.71	1.71	1.71	1.71	
		15 Park	.229	50 - 78	28	.85	5.45	4.48	3.50	2.53	
		TOTAL			34		7.16	6.19	5.21	4.24	
8	1969	22 King	.335	33 - 41	8	.85	2.28	2.28	2.28	2.28	
		82 Augusta	.335	42 - 69	27	.85	7.69	6.26	4.84	3.42	
		TOTAL			35		9.97	8.54	7.12	5.70	
9	1975	24 Marsh	1.203	40 - 41	1	.6	.72	.72	.72	.72	
		35 John	.335	41 - 45	4	.6	.80	.80	.80	.80	
		178 John	3.174	45 - 75	30	.6	57.13	47.61	38.09	28.57	
		TOTAL			35		58.65	49.13	39.61	30.09	

EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 3 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.) 0 Latency	5 yr	10 yr	15 yr	Comments
10	1974	Durham	.335	35 - 37	2	.6	.40	.40	.40	.40	
		Pine	.318	37 - 39	2	.6	.38	.38	.38	.38	
		69 Walton	.318	39 - 41	2	.6	.38	.38	.38	.38	
		Park	.318	41 - 43	2	.6	.38	.38	.38	.38	
		Cavan	.318	43 - 45	2	.6	.38	.38	.38	.38	
		198 Bruton	.335	45 - 46	1	.6	.20	.20	.20	.20	
		84 Charles	.335	46 - 51	5	.85	1.42	1.42	1.42	1.42	
		76 Charles	.243	51 - 54	3	.85	.62	.62	.62	.62	
		159 Hope North	.243	54 - 56	2	.6	.29	.29	.29	.29	
		RR#4 Cobourg Rd.	.229	57 - 60	3	.6	.41	.41	.41	.14	
		RR#4 Cobourg Rd.	.229	60 - 63	3	.85	.58	.58	.58	-	
		64 Toronto	.243	63 - 74	11	.85	2.27	1.23	.21	-	
		TOTAL			38		7.71	6.67	5.65	4.59	
11	1975	24 Smith	.224	33 - 59	26	.6	3.49	3.49	3.49	3.49	
		24 Smith	.224	59 - 75	16	.85	3.05	2.09	1.14	.19	
		TOTAL			42		6.54	5.58	4.63	3.68	
12	1975	Ellen	.318	33 - 36	3	.85	.81	.81	.81	.81	
		65 Smith	.224	36 - 39	3	.6	.40	.40	.40	.40	
		65 Smith	2.098	39 - 51	12	.6	15.11	15.11	15.11	15.11	1939 Contnm.
		John	.318	51 - 55	4	.6	.76	.76	.76	.76	lapse 1956
		Cavan	.318	57 - 60	3	.6	.57	.57	.57	.57	
		12 Arthur	.229	60 - 67	7	.6	.96	.96	.69	-	
		20 Fraser	.229	67 - 70	3	.6	.41	.41	-	-	
		99 Phillips	.318	70 - 75	5	.6	.95	-	-	-	
		TOTAL			40		19.97	19.02	18.34	17.65	

EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 4 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.) 0 Latency	5 yr	10 yr	15 yr	Comments
13	1969	Armour	.318	34 - 35	1	.6	.19	.19	.19	.19	
		92 King	.318	35 - 53	18	.6	3.43	3.43	3.43	3.43	
		24 College	.229	53 - 69	16	.6	2.20	1.51	.82	.14	
		TOTAL			35		5.82	5.13	4.44	3.76	
14	1975	12 Bramley	.318	33 - 36	3	.85	.81	.81	.81	.81	
		75 Dorset	.318	36 - 38	2	.85	.54	.54	.54	.54	
		Marsh Rd.	.335	38 - 39	1	.85	.28	.28	.28	.28	
		211 Walton	.335	39 - 41	2	.85	.57	.57	.57	.57	
		86 John	.318	41 - 50	9	.85	2.43	2.43	2.43	2.43	
		136 Elgin	.335	50 - 53	3	.85	.85	.85	.85	.85	
		134 Elgin	.229	53 - 75	22	.85	4.28	3.31	2.34	1.36	
		TOTAL			42		9.76	8.79	7.82	6.84	
15	1973	Smith	.335	33 - 40	7	.6	1.41	1.41	1.41	1.41	
		80 Walton	.318	40 - 57	17	.6	3.24	3.24	3.24	3.24	
		80 Walton	.318	57 - 73	16	.85	4.32	2.97	1.62	.27	
		TOTAL			40		8.97	7.62	6.27	4.92	
16	1976	186 John	.318	33 - 37	4	.6	.76	.76	.76	.76	no contam as yet
		Ward	.318	37 - 38	1	.85	.27	.27	.27	.27	
		Bedford	.318	38 - 41	3	.85	.81	.81	.81	.81	
		Hope	.318	41 - 43	2	.85	.54	.54	.54	.54	
		79 Smith	6.636	43 - 65	22	.85	124.09	124.09	124.09	101.53	
		79 Smith	6.636	65 - 75	10	.6	39.82	23.89	3.98	-	
		79 Smith	6.636	75 - 76	1	.85	5.41	-	-	-	
		TOTAL			43		171.70	150.36	130.45	103.91	

EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 5 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.)				Comments
							0 Latency	5 yr	10 yr	15 yr	
17	1972	148 Dorset East	.229	49 - 50	1	.6	.14	.14	.14	.14	
		275 Ridout	.229	50 - 54	4	.6	.55	.55	.55	.55	
		43 Dorset West	.229	54 - 60	6	.6	.82	.82	.82	.41	
		78 Ward	.229	60 - 72	12	.6	1.65	.96	.27	-	
		TOTAL			23		3.16	2.47	1.78	1.10	
18	1977	John	.318	48 - 50	2	.6	.38	.38	.38	.38	
		Smith	.335	50 - 52	2	.6	.40	.40	.40	.40	
		52 Cavan	.318	52 - 57	5	.6	.95	.95	.95	.95	
		42 Young	.229	57 - 77	20	.6	2.75	2.06	1.37	.69	
		TOTAL			29		4.48	3.79	3.10	2.42	
19	1980	Hope South	.335	33 - 34	1	.6	.20	.20	.20	.20	
		Mill	.335	34 - 35	1	.6	.20	.20	.20	.20	lapse 1936-39
		1 Armour	.335	40 - 42	2	.6	.40	.40	.40	.40	
		10 Armour	.335	42 - 45	3	.6	.60	.60	.60	.60	
		8 Brown	.224	45 - 72	27	.6	3.63	3.63	3.36	2.69	
		8 Brown	.224	72 - 80	8	.85	1.52	.57	-	-	
		TOTAL			42		7.65	5.60	4.76	4.09	
20	1976	14 Ward	.229	33 - 60	27	.6	3.71	3.71	3.71	3.71	
		14 Ward	.229	60 - 76	16	.85	3.11	2.14	1.17	.19	
		TOTAL			43		6.82	5.85	4.88	3.90	
21	1977	77 Francis	.229	33 - 62	29	.6	3.98	3.98	3.98	3.98	
		51 McCaul	.229	62 - 77	15	.6	2.06	1.37	.69	-	
		TOTAL			44		6.04	5.35	4.67	3.98	

EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 6 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.)				Comments
							0 Latency	5 yr	10 yr	15 yr	
22	1976	Bedford	.335	36 - 37	1	.6	.20	.20	.20	.20	lapse 1940-44
		John	.335	37 - 49	2	.6	.40	.40	.40	.40	
		23 Baldwin	.229	45 - 46	1	.6	.14	.14	.14	.14	
		1 Jocelyn	.229	46 - 76	30	.6	4.12	3.44	2.75	2.06	
		TOTAL			34		4.86	4.18	3.49	2.80	
23	1975	Ward	.335	33 - 36	3	.6	.60	.60	.60	.60	
		8 King	.229	36 - 50	14	.6	1.92	1.92	1.92	1.92	
		15 Victoria	.229	50 - 56	6	.6	.82	.82	.82	.82	
		15 Victoria	.229	56 - 75	19	.85	3.70	2.73	1.75	.78	
		TOTAL			42		7.04	6.07	5.09	4.12	
24	1969	64 Sherbourne	.229	33 - 68	35	.6	4.81	4.26	3.57	2.89	
		64 Sherbourne	.229	68 - 69	1	.85	.19	-	-	-	
		TOTAL			36		5.00	4.26	3.57	2.89	
25	1974	32 Ralston	.243	57 - 61	4	.6	.58	.58	.58	.29	
		346 Lakeshore	.229	61 - 70	9	.6	1.24	1.10	.41	-	
		346 Lakeshore	.229	70 - 74	4	.85	.78	-	-	-	
		TOTAL			17		2.60	1.68	.99	.29	
26	1975	24 Walton	.318	55 - 56	1	.6	.19	.19	.19	.19	
		Ontario	.229	56 - 58	2	.6	.27	.27	.27	.14	lapse 1962-63
		56 Ellen	.229	58 - 61	3	.6	.41	.41	.41	-	
		93 Mill North	.229	64 - 66	2	.6	.27	.27	.14	-	
		25 Bloomsgrove	.229	66 - 69	3	.6	.41	.41	-	-	
		127 Charles	.229	69 - 75	6	.6	.82	.14	-	-	
		TOTAL			17		2.37	1.69	1.01	.33	

EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 7 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.) 0 Latency	5 yr	10 yr	15 yr	Comments
27	1977	246 Walton	.229	33 - 40	7	.6	.96	.96	.96	.96	
		223 Walton	.229	40 - 77	37	.6	5.08	4.40	3.71	3.02	
		TOTAL			44		6.04	5.36	4.67	3.98	
28	1975	6 Percival	.243	48 - 64	16	.6	2.33	2.04	1.31	.58	lapse 1965-75
		6 Percival	.243	72 - 75	3	.6	.44	-	-	-	
		TOTAL			19		2.77	2.04	1.31	.58	
29	1972	124 Ontario	.229	47 - 58	11	.6	1.51	1.51	1.51	1.37	
		124 Ontario	.229	58 - 72	14	.85	2.72	1.75	.78	-	
		TOTAL			25		4.23	3.26	2.29	1.37	
30	1975	31 College	.229	33 - 51	18	.6	2.47	2.06	1.37	.69	lapse 1952-73
		5 Durham	.229	73 - 75	2	.6	.27	-	-	-	
		TOTAL			20		2.74	2.06	1.37	.69	
31	1971	124 Ontario	.229	48 - 63	15	.6	2.06	2.06	1.79	1.10	
		124 Ontario	.229	63 - 71	8	.85	1.56	.58	-	-	
		TOTAL			23		3.62	2.64	1.79	1.10	
32	1970	Various Apts.	.318	46 - 56	10	.6	1.91	1.91	1.91	1.72	
		53 Caroline	.229	56 - 63	7	.6	.96	.96	.55	-	
		109 Elgin S.	.229	63 - 70	7	.6	.96	.27	-	-	
		TOTAL			24		3.83	3.14	2.46	1.72	

EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 8 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.)				Comments
							0 Latency	5 yr	10 yr	15 yr	
33	1979	2 Chestnut	.229	33 - 46	13	.6	1.79	1.79	1.79	1.79	
		1 Chestnut	.229	46 - 62	16	.6	2.20	2.20	2.20	2.20	
		4 Chestnut	.229	62 - 69	7	.6	.96	.96	.96	.27	
		78 Augusta	.229	69 - 79	10	.6	1.37	.69	-	-	
		TOTAL			46		6.32	5.64	4.95	4.26	
34	1971	Pine S.	.335	33 - 45	12	.6	2.41	2.41	2.41	2.41	
		46 Dorset	.229	45 - 66	21	.6	2.88	2.75	2.06	1.37	
		46 Dorset	.229	66 - 70	4	.85	.78	-	-	-	
		TOTAL			37		6.07	5.16	4.47	3.78	
35	1972	74 Cavan	.730	61 - 69	8	.6	3.50	2.63	.44	-	
		74 Cavan	.730	69 - 72	3	.85	2.48	-	-	-	
		TOTAL			11		5.98	2.63	.44	-	
36	1969	Cavan	.335	33 - 36	3	.6	.60	.60	.60	.60	
		17 King	.229	36 - 49	13	.6	1.79	1.79	1.79	1.79	
		15 Park	.229	49 - 66	17	.6	2.34	2.06	1.37	.69	
		12 Caroline	.229	66 - 69	3	.6	.41	-	-	-	
		TOTAL			36		5.14	4.45	3.76	3.08	
37	1975	59 Charles	.335	39 - 41	2	.6	.40	.40	.40	.40	lapse 1942-50
		5 Bedford	.229	51 - 59	8	.6	1.10	1.10	1.10	1.10	
		223 Hope N.	.229	59 - 74	16	.6	2.20	1.51	.82	.14	
		TOTAL			26		3.70	3.01	2.32	1.64	
38	1972	74 Mill South	.224	33 - 72	39	.6	5.24	4.57	3.90	3.23	
		TOTAL			39		5.24	4.57	3.90	3.23	

EXPOSURE SUMMARY SHEET Proj. 300[illegible] Sheet [illegible] of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.) 0 Latency	5 yr	10 yr	15 yr	Comments
39	1980	49 Sullivan	.335	38 - 39	1	.6	.20	.20	.20	.20	
		47 Harcourt	.335	39 - 41	2	.6	.40	.40	.40	.40	
		32½ Bramley South	.335	41 - 64	23	.6	4.62	4.62	4.62	4.62	
		11 Thomas	.229	64 - 65	1	.6	.14	.14	.14	.14	
		81 Dorset West	.229	65 - 68	3	.6	.41	.41	.41	-	
		81 Dorset West	.229	68 - 70	2	.85	.39	.39	.39	-	
		18 Walton	.318	70 - 71	1	.85	.27	.27	-	-	
		81 Bruton	.229	71 - 76	5	.85	.97	.78	-	-	
		91 Mill North	.229	76 - 80	4	.85	.78	-	-	-	
		TOTAL			42		8.18	7.21	6.16	5.36	
40	1972	63 Molson	.243	36 - 67	31	.6	4.52	4.52	3.79	3.06	
		63 Molson	.243	67 - 72	5	.85	1.03	-	-	-	
		TOTAL			36		5.55	4.52	3.79	3.06	
41	1969	17 Shuter	.229	33 - 64	31	.6	4.26	4.26	3.57	2.89	
		17 Shuter	.229	64 - 65	1	.85	.19	-	-	-	
		128 King	2.925	65 - 69	4	.85	9.94	-	-	-	
		TOTAL			36		14.39	4.25	3.57	2.89	
42	1972	25 Smith	.335	39 - 41	2	.6	.40	.40	.40	.40	
		124 John	.335	41 - 48	7	.6	1.40	1.40	1.40	1.40	
		110 Strachan	.229	48 - 62	14	.6	1.92	1.92	1.92	1.24	
		38 Smith	.229	62 - 72	10	.6	1.37	.69	-	-	
		TOTAL			33		5.09	4.41	3.72	3.04	
43	1975	28 Bramley	.229	33 - 75	42	.6	5.77	5.08	4.40	3.71	
		TOTAL			42		5.77	5.08	4.40	3.71	

EXPOSURE SUMMARY SHEET   Proj. 300[illegible]   Sheet 10 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.) 0 Latency	5 yr	10 yr	15 yr	Comments
44	1974	10 Little Hope	.229	49 - 50	1	.6	.14	.14	.14	.14	
		4 Ellen	.229	50 - 52	2	.6	.28	.28	.28	.28	
		8 Margaret	.335	52 - 53	1	.6	.20	.20	.20	.20	
		55 Brown	.335	53	1	.6	.20	.20	.20	.20	
		Ridout	.229	53 - 55	2	.6	.28	.28	.28	.28	
		91 Mill N.	.229	55 - 56	1	.6	.14	.14	.14	.14	
		31 Bramley S	.229	56 - 57	1	.6	.14	.14	.14	.14	
		64 Ellen	.229	57 - 61	4	.6	.55	.55	.55	.14	
		28 John	.224	61 - 62	2	.6	.27	.27	.27	-	
		80 Princess	.229	62 - 70	8	.6	1.10	.69	-	-	
		24 Queen	.224	72 - 74	2	.85	.38	-	-	-	
		TOTAL			25		3.68	2.89	2.20	1.52	
45		6 Alexander	.318	41 - 51	10	.6	1.91	1.91	1.91	1.91	
		58 Bramley South	.229	51 - 72	21	.6	2.88	2.20	1.51	.82	
		TOTAL			31		4.79	4.11	3.42	2.73	
46	1971	Cavan	.335	33 - 61	28	.85	7.97	7.97	7.97	6.55	
		71 Pine	.229	61 - 71	10	.85	1.95	.97	-	-	
		TOTAL			38		9.92	8.94	7.97	6.55	
47	1976	Walton	.318	33 - 34	1	.6	.19	.19	.19	.19	
		John	.224	34 - 39	5	.6	.67	.67	.67	.67	lapse 1940-42
		130 Walton	.229	43 - 48	5	.6	.69	.69	.69	.69	
		16 Percival	.229	48 - 76	28	.6	3.85	3.16	2.47	1.79	
		TOTAL			39		5.40	4.71	4.02	3.34	
48	1977	67 Hope North	.254	48 - 58	10	.6	1.52	1.52	1.52	1.52	
		10 King	.229	58 - 77	19	.6	2.61	1.92	1.23	.55	
		TOTAL			29		5.13	3.44	2.75	2.07	

EXPOSURE SUMMARY SHEET

Proj. 30603 Sheet 1 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.)				Comments
							0 Latency	5 yr	10 yr	15 yr	
49	1978	181 Victoria N.	.335	33 - 52	19	.6	3.819	3.819	3.819	3.819	
		69 Dorset E.	.229	52 - 58	6	.6	.82	.82	.82	.82	
		69 Dorset E.	.229	58 - 78	20	.85	3.89	2.92	1.95	.97	
		TOTAL			45		8.53	7.56	6.59	5.61	
50	1973	55 Caroline	.229	49 - 51	2	.6	.27	.27	.27	.27	
		46 Caroline	.229	51 - 61	10	.6	1.37	1.37	1.37	.96	
		46 Caroline	.229	61 - 73	12	.85	2.34	1.36	.39	-	
		TOTAL			24		3.98	3.00	2.03	1.23	
51*	1978	61 King	.229	67 - 78	11	.6	1.51	.82	.14	-	
	1979	61 King	.229	67 - 79	12	.6	1.65	.96	.27	-	
	1980	61 King	.229	67 - 80	13	.6	1.79	1.10	.41	-	
	1981	61 King	.229	67 - 81	14	.6	1.92	1.23	.55	-	
52	1969	50 Sullivan	.229	55 - 61	6	.6	182	.82	.55	-	
		53 Francis	.229	61 - 69	8	.6	1.10	.41	-	-	
		TOTAL			14		1.92	1.23	.55	-	
53	1975	Trinity College	.318	43 - 47	4	.85	1.08	1.08	1.08	1.08	lapse 1948-54
		Trinity College	.318	55 - 60	5	.85	1.35	1.35	1.35	.81	
		Roseglen & Dorset E.	.229	60 - 67	7	.6	.96	.96	.41	-	
		Trinity College	.318	68 - 71	3	.85	.81	.27	-	-	
		Roseglen & Dorset E.	.229	72 - 75	3	.6	.41	-	-	-	
		TOTAL			22		4.61	3.66	2.84	1.89	
54	1975	Alexander	.335	33 - 35	2	.6	.40	.40	.40	.40	
		36 Victoria South	.229	35 - 74	39	.6	5.36	4.81	4.12	3.44	
		36 Victoria South	.229	74 - 75	1	.85	.19	-	-	-	
		TOTAL			42		5.95	5.21	4.52	3.84	

* exact year of final exposure uncertain at time of report preparation

EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 12 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.) 0 Latency	5 yr	10 yr	15 yr	Comments
55	1974	8 Alexander	.224	33 - 53	20	.6	2.69	2.69	2.69	2.69	
		219 Hope North	.229	53 - 74	21	.6	2.89	2.20	1.51	.82	
		TOTAL			41		5.58	4.89	4.20	3.51	
56	1969	148 Walton	.335	38 - 30	1	.85	.29	.29	.29	.29	
		1 Deblaquire South	.335	39 - 40	1	.85	.29	.29	.29	.29	Rn problem home.Too early for contaminat.
		12 Elgin South	.229	40 - 61	21	.85	4.09	4.09	3.69	2.73	
		12 Elgin South	.229	61 - 69	8	.6	1.10	.41	-	-	
		TOTAL			31		5.77	5.08	4.27	3.31	
57	1975	65 Smith	.335	33 - 39	6	.85	1.70	1.70	1.70	1.70	
		65 Smith	2.098	39 - 48	9	.85	16.05	16.05	16.05	16.05	cont.start 39
		16½ Mill South	.229	56 - 60	4	.6	.55	.55	.55	.55	lapse 1949-55
		199 Walton	.229	60 - 63	3	.6	.41	.41	.41	-	
		92 Elgin North	.229	63 - 75	12	.6	1.65	.96	.27	-	
		TOTAL			34		20.36	19.67	18.98	18.30	
58	1974	Ellen	.335	33 - 36	3	.6	.60	.60	.60	.60	
		40 Sherbourne	.335	36 - 48	12	.85	3.42	3.42	3.42	3.42	
		18 Walton	.318	48 - 53	5	.6	.95	.95	.95	.95	
		Ridout	.229	53 - 54	1	.6	.14	.14	.14	.14	
		Ridout	.229	54 - 56	2	.6	.27	.27	.27	.27	
		80 Walton	.318	56 - 65	9	.6	1.72	1.72	1.72	.76	
		63 Ellen	.229	65 - 65	1	.6	.14	.14	-	-	
		40½ Walton	.224	65 - 72	7	.6	.94	.54	-	-	
		31 Victoria South	.229	72 - 74	2	.6	.27	-	-	-	
		TOTAL			42		8.45	7.78	7.10	6.14	

EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 13 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.) 0 Latency	5 yr	10 yr	15 yr	Comments
59	1970	9 Victoria S.	.335	33 - 35	2	.6	.40	.40	.40	.40	
		9½ Victoria S.	.229	35 - 70	35	.6	4.81	4.12	3.44	2.75	
		TOTAL			37		5.21	4.52	3.84	3.15	
60	1974	70 Bramley S.	.229	45 - 57	12	.6	1.65	1.65	1.65	1.65	
		14 Cumberland	.229	57 - 60	3	.6	.41	.41	.41	.27	
		14 Cumberland	.229	60 - 74	14	.85	2.73	1.75	.78	-	
		TOTAL			29		4.79	3.81	2.84	1.92	
61	1972	18 John	.335	44 - 48	4	.6	.80	.80	.80	.80	
		Ganaraska Hotel	.318	48 - 51	3	.6	.57	.57	.57	.57	
		Peter	.229	51 - 54	3	.6	.41	.41	.41	.41	
		83 Hope South	.229	54 - 56	2	.6	.27	.27	.27	.27	
		1 Deblaquire S.	.659	56 - 72	16	.6	6.33	4.35	2.37	.40	
		TOTAL			28		8.38	6.40	4.42	2.45	
62	1971	136 Walton	.318	33 - 41	8	.85	2.16	2.16	2.16	2.16	
		Dorset	.229	41 - 47	6	.85	1.16	1.16	1.16	1.16	
		36 Princess	.229	47 - 71	24	.85	4.67	3.70	2.73	1.75	
		TOTAL			38		7.99	7.02	6.05	5.07	
63	1969	41 Ellen	.229	55 - 65	10	.6	1.37	1.24	.55	-	
		136 Ontario	.229	65 - 66	1	.6	.14	-	-	-	
		136 Ontario	.229	66 - 69	3	.85	.58	-	-	-	
		TOTAL			14		2.09	1.24	.55	-	
64	1978	McCaul	.335	46 - 48	2	.6	.40	.40	.40	.40	
		56 Bruton	.229	49 - 71	22	.6	3.02	3.02	2.61	1.92	
		56 Bruton	.229	71 - 77	6	.85	1.17	.19	-	-	
		Regency Manor	.224	77 - 78	1	.85	.19	-	-	-	
		TOTAL			31		4.78	3.61	3.01	2.32	

EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 14 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.)				Comments
							0 Latency	5 yr	10 yr	15 yr	
65	1972	182 Hope South	.636	50 - 72	22	.6	8.40	6.49	4.58	2.67	
		TOTAL			22		8.40	6.49	4.58	2.67	
66	1975	Queen's Hotel	.318	50 - 64	14	.85	3.78	3.78	3.78	2.70	
		Ganaraska Hotel	.318	64 - 70	6	.85	1.62	1.62	.27	-	
		12 Ward	.229	70 - 75	5	.6	.69	-	-	-	
		TOTAL			25		6.09	5.30	4.05	2.70	
67	1969	93 Francis	.335	47 - 50	3	.85	.85	.85	.85	.85	
		94 Hope South	.229	50 - 58	8	.85	1.56	1.56	1.56	.78	
		101 Hope North	.229	58 - 69	11	.85	2.14	1.16	.19	-	
		TOTAL			22		4.55	3.57	2.60	1.63	
68	1978	19 Park	.229	33 - 55	22	.6	3.02	3.02	3.02	3.02	
		19 Park	.229	55 - 78	23	.85	4.48	3.50	2.53	1.56	
		TOTAL			45		7.50	6.52	5.55	4.58	
69	1975	14 Clovelly	.229	63 - 66	3	.85	.58	.58	.39	-	
		12 Walnut	.243	66 - 74	8	.85	1.65	.83	-	-	
		12 Walnut	.243	74 - 75	1	.6	.15	-	-	-	
		TOTAL			12		2.38	1.41	.39	-	
70	1976	1 Walton	.318	37 - 39	2	.85	.54	.54	.54	.54	
		Brown	.335	39 - 40	1	.85	.28	.28	.28	.28	
		78 Cavan	.229	41 - 75	34	.85	6.62	5.64	4.67	3.70	
		TOTAL			37		7.44	6.46	5.49	4.52	
71	1975	4 Ellen	.335	33 - 36	3	.85	.85	.85	.85	.85	
		17 Bramley North	.229	36 - 75	39	.85	7.59	6.62	5.64	4.67	
		TOTAL			42		8.44	7.47	6.49	5.52	

EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 15 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.)				Comments
							0 Latency	5 yr	10 yr	15 yr	
72	1979	28 John	.318	42 - 42	1	.6	.19	.19	.19	.19	
		168 King	.335	42 - 45	3	.6	.60	.60	.60	.60	
		14 Madison	.335	45 - 60	15	.6	3.02	3.02	3.02	3.02	
		71 Dorset W.	.229	60 - 79	19	.6	2.61	1.92	1.24	.55	
		TOTAL			38		6.42	5.73	5.05	4.36	
73	1974	80 Walton	.318	47 - 62	15	.85	4.05	4.05	4.05	3.24	
		60 Francis	.229	62 - 74	12	.85	2.34	1.36	.39	-	
		TOTAL			27		6.39	5.41	4.44	3.24	
74	1976	12 Ward	.335	46	1	.85	.28	.28	.28	.28	
		75 Francis	.229	46 - 76	30	.85	5.84	4.87	3.89	2.92	
		TOTAL			31		6.12	5.15	4.17	3.20	
75	1973	318 Ridout	.229	33 - 51	28	.6	3.85	3.85	3.85	3.44	
		318 Ridout	.229	61 - 73	12	.85	2.34	1.36	.39	-	
		TOTAL			40		6.19	5.21	4.24	3.44	
76	1972	Queens Hotel	.318	51 - 53	2	.6	.38	.38	.38	.38	
		Brown	.335	53 - 56	3	.6	.60	.60	.60	.60	
		Queens Hotel	.318	56 - 73	16	.85	4.32	2.97	1.62	.27	
		TOTAL			21		5.30	3.95	2.60	1.25	
77	1978	23 Durham	.229	65 - 75	10	.6	1.37	1.10	.41	-	
		58 Crossley	.385	75 - 76	1	.6	.23	-	-	-	
		RR #4 Cobourg	.229	76 - 78	2	.6	.27	-	-	-	
		TOTAL			13		1.87	1.10	.41	-	

EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 16 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.) 0 Latency	5 yr	10 yr	15 yr	Comments
78	1972	Bramley	.229	33 - 35	2	.6	.27	.27	.27	.27	
		Durham	.229	35 - 39	4	.6	.55	.55	.55	.55	
		Sullivan	.229	39 - 40	1	.6	.14	.14	.14	.14	
		115 Sherbourne	.229	40 - 70	30	.6	4.12	3.71	3.02	2.33	
		115 Sherbourne	.229	70 - 72	2	.85	.39	-	-	-	
		TOTAL			39		5.47	4.67	3.98	3.29	
79	1970	Walton	.229	46 - 48	2	.6	.27	.27	.27	.27	
		9 Pine North	.229	48 - 64	16	.6	2.20	2.06	1.51	.96	
		9 Pine North	.229	64 - 70	6	.85	1.16	.19	-	-	
		TOTAL			24		3.63	2.52	1.78	1.23	
80	1974	20 Durham	.335	33 - 38	5	.6	1.00	1.00	1.00	1.00	
		20 Durham	.335	38 - 43	5	.85	1.42	1.42	1.42	1.42	
		9 Pine North	.229	43 - 58	15	.6	2.06	2.06	2.06	2.06	
		9 Pine North	.229	58 - 74	16	.85	3.11	2.14	1.17	.19	
		TOTAL			31		7.59	6.62	5.65	4.67	
81	1971	83 Strachan	.229	33 - 62	29	.6	3.98	3.98	3.84	3.16	
		83 Strachan	.229	62 - 71	9	.85	1.75	.78	-	-	
		TOTAL			38		5.73	4.76	3.84	3.16	
82	1970	11 Oxford	.229	53 - 70	17	.6	2.33	1.65	.96	.27	
		TOTAL			17		2.33	1.65	.96	.27	

EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 17 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.) 0 Latency	5 yr	10 yr	15 yr	Comments
83	1980	38 John	.229	33 - 34	1	.6	.14	.14	.14	.14	
		3 Cavan	.229	34 - 35	1	.6	.14	.14	.14	.14	
		17 Park	.229	35 - 38	3	.6	.41	.41	.41	.41	
		12 Park	.229	38 - 41	3	.6	.41	.41	.41	.41	
		Walton	.229	41	1	.6	.14	.14	.14	.14	
		1 Sherbourne	.229	41 - 42	1	.6	.14	.14	.14	.14	
		20 Bloomsgrove	.229	42 - 52	10	.6	1.37	1.37	1.37	1.37	
		11 North	.229	52 - 57	5	.6	.69	.69	.69	.69	
		Julia	.229	57 - 50	2	.6	.27	.27	.27	.27	
		48 John	.224	59 - 80	21	.6	2.82	2.15	1.48	.81	
		TOTAL			48		6.53	5.86	5.19	4.52	
84	1977	John	.224	69 - 71	2	.6	.27	.27	-	-	
		Smith	.229	71 - 72	1	.6	.14	.14	-	-	
		18 Walton	.224	72 - 77	5	.6	.67	-	-	-	
		TOTAL			8		1.08	.41	-	-	
85	1975	Robertson	.229	54 - 57	3	.6	.41	.41	.41	-	
		Toronto	.229	57 - 59	2	.6	.27	.27	-	-	
		47 Cavan	.229	59 - 61	2	.6	.27	.27	-	-	lapse 1962-68
		45 Ontario	.229	69 - 75	6	.6	.82	.14	-	-	
		TOTAL			13		1.77	1.09	.41	-	
86	1972	9 Park	.229	33 - 71	38	.6	5.22	4.67	3.98	3.30	
		9 Park	.229	71 - 72	1	.85	.19	-	-	-	
		TOTAL			39		5.41	4.67	3.98	3.30	
87	1978	53 Victoria	.229	52 - 61	9	.6	1.23	1.23	1.23	1.23	
		7 Fraser	.229	61 - 78	17	.6	2.33	1.65	.96	.28	
		TOTAL			26		3.56	2.88	2.19	1.51	

EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 18 of24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.) 0 Latency	5 yr	10 yr	15 yr	Comments
88	1974	28 Shuter	.229	33 - 54	21	.6	2.89	2.89	2.89	2.89	
		28 Shuter	.229	54 - 74	20	.85	3.89	2.92	1.95	.97	
		TOTAL			41		6.78	5.81	4.84	3.86	
89	1968	286 Ridout	.335	54 - 57	3	.6	.60	.60	.60	-	
		112 Bruton	.335	57 - 59	2	.6	.40	.40	.20	-	
		51 Molson	.253	59 - 68	9	.6	1.37	.61	-	-	
		TOTAL			14		2.37	1.61	.80	-	
90	1972	190 John	4.67	45 - 72	27	.6	75.65	61.64	47.63	33.62	
		TOTAL					75.65	61.65	47.63	33.62	
91	1972	Beamish	.229	55 - 72	17	.85	3.31	2.34	1.36	.39	
		TOTAL					3.31	2.34	1.36	.39	
92	1977	53 Walton	.318	45 - 74	29	.85	7.84	7.30	5.95	4.60	
		68 Francis	.335	74 - 77	3	.6	.60	-	-	-	
		TOTAL			32		8.44	7.30	5.95	4.60	
93	1975	158 King	.318	59 - 60	1	.6	.19	.19	.19	.19	
		14 Madison	.224	60 - 65	5	.6	.67	.67	.67	-	
		14 Madison	.224	65 - 75	10	.85	1.90	.95	-	-	
		TOTAL			16		2.76	1.81	.86	.19	
94	1976	83 Debalquire	.229	47 - 76	29	.6	3.98	3.30	2.61	1.92	
		TOTAL			29		3.98	3.30	2.61	1.92	

EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 19 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.) 0 Latency	5 yr	10 yr	15 yr	Comments
95	1976	70 Brown	.335	68 - 69	1	.6	.20	.20	-	-	
		236 Ontario	.335	70 - 73	3	.6	.60	.20	-	-	
		183 Walton	.335	73 - 76	3	.6	.60	-	-	-	
		TOTAL			7		1.40	.40	-	-	
96	1969	Victoria	.318	40 - 45	5	.85	1.35	1.35	1.35	1.35	
		94 Dorset W.	.318	46 - 51	5	.85	1.35	1.35	1.35	1.35	
		74 Pine	.229	51 - 57	6	.85	1.17	1.17	1.17	.39	
		342 Lakeshore	.229	58 - 69	11	.85	2.14	1.16	.19	-	
		TOTAL			27		6.01	5.03	4.06	3.09	
97	1974	Ellen	.335	33 - 37	4	.6	.80	.80	.80	.80	
		100 Charles	.335	37 - 59	22	.6	4.42	4.42	4.42	4.42	
		148 Victoria	.229	59 - 73	14	.6	1.92	1.37	.69	-	
		148 Victoria	.229	73 - 74	1	.85	.19	-	-	-	
		TOTAL			41		7.33	6.59	5.91	5.22	
98	1975	83 Elgin N.	.229	40 - 41	1	.6	.14	.14	.14	.14	
		Charles	.229	41 - 42	1	.6	.14	.14	.14	.14	
		98 Dorset	.229	43 - 75	32	.6	4.40	3.71	3.02	2.33	
		TOTAL			34		4.68	3.99	3.30	2.61	
99	1977	24 Barrett	.229	52 - 72	20	.6	2.74	2.74	2.06	1.37	
		24 Barrett	.229	72 - 77	5	.85	.97	-	-	-	
		TOTAL			25		3.71	2.74	2.06	1.37	
100	1971	Smith	.335	33 - 37	4	.85	1.14	1.14	1.14	1.14	
		88 King	.253	37 - 71	34	.85	7.31	6.24	5.16	4.09	
		TOTAL			38		8.45	7.38	6.30	5.23	

EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 20 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.)				Comments
							0 Latency	5 yr	10 yr	15 yr	
101	1976	81 Mill S.	.318	8 - 42	4	.6	.76	.76	.76	.76	
		27 Harris	.229	42 - 67	25	.6	3.44	3.44	3.29	2.61	
		29 Harris	1.97	67 - 73	6	.6	7.09	4.73	-	-	
		29 Harris	1.97	73 - 76	3	.85	5.02	-	-	-	
		TOTAL			38		16.31	8.93	4.05	3.37	
102	1974	96 Pine S.	.229	33 - 50	17	.6	2.34	2.34	2.34	2.34	
		85 John	.229	50 - 51	1	.6	.14	.14	.14	.14	
		85 John	.229	51 - 70	19	.85	3.70	3.50	2.53	1.56	
		9 Lyn	.253	70 - 74	4	.85	.86	-	-	-	
		TOTAL			41		7.04	5.98	5.01	4.04	
103	1974	55 King	.335	48 - 62	14	.85	3.99	3.99	3.99	3.13	
		193 Walton	.229	62 - 64	2	.85	.39	.39	.39	-	
		Hope N.	.229	64 - 74	10	.85	1.95	.97	-	-	
		TOTAL			26		6.33	5.35	4.38	3.13	
104	1975	4 Keith	.253	66 - 75	9	.6	1.37	.61	-	-	
		TOTAL			9		1.37	.61	-	-	
105	1974	Pine	.335	35 - 37	2	.6	.40	.40	.40	.40	
		74 Dorset	.318	37 - 50	13	.6	2.48	2.48	2.48	2.48	
		32 Harcourt	.229	50 - 68	18	.6	2.47	2.47	1.92	1.24	
		32 Harcourt	.229	68 - 74	6	.85	1.16	.19	-	-	
		TOTAL			39		6.51	5.54	4.80	4.12	
106	1972	7 Sullivan	.229	65 - 66	1	.6	.14	.14	-	-	
		34 Hope N.	.229	66 - 72	6	.6	.82	.14	-	-	
		TOTAL			7		.96	.28	-	-	

EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 21 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.)				Comments
							0 Latency	5 yr	10 yr	15 yr	
107A	1977	28 Baldwin	.229	59 - 61	2	.6	.27	.27	.27	.27	
		80 Dorset E.	.229	61 - 70	9	.6	1.24	1.24	.82	.14	
		80 Dorset E.	.229	70 - 77	7	.85	1.36	.39	-	-	
		TOTAL			18		2.87	1.90	1.09	.41	
107B	1969	12 Ellen	.335	33 - 40	7	.85	1.99	1.99	1.99	1.99	
		33 Ellen	.335	40 - 42	2	.85	.57	.57	.57	.57	
		38 Margaret	.229	42 - 69	27	.85	5.26	4.28	3.30	2.33	
		TOTAL			36		7.82	6.84	5.86	4.89	
108	1974	31 Princess	.335	33 - 35	2	.6	.40	.40	.40	.40	
		King	.335	35 - 36	1	.6	.20	.20	.20	.20	
		96 Sherbourne	.335	36 - 37	1	.6	.20	.20	.20	.20	
		9 Little Hope	.335	37 - 39	2	.6	.40	.40	.40	.40	
		46 Hope S.	.335	39 - 47	8	.6	1.60	1.60	1.60	1.60	
		Old Firehall	.318	47 - 49	2	.6	.38	.38	.38	.38	
		46 Hope S.	.335	49 - 60	11	.6	2.21	2.21	2.21	2.01	
		96 Sherbourne	.229	60 - 69	9	.5	1.24	1.24	.55	-	
		96 Sherbourne	.229	69 - 74	5	.85	.97	-	-	-	
		TOTAL			41		7.60	6.63	5.94	5.19	
109	1976	1 Southby Pl.	.229	64 - 68	4	.6	.55	.55	.27	-	
		1 Southby Pl.	.229	68 - 76	8	.85	1.56	.58	-	-	
		TOTAL			12		2.11	1.13	.27	-	
110	1976	15 Martha	.229	33 - 76	43	.6	5.91	5.22	4.53	3.85	
		TOTAL			43		5.91	5.22	4.53	3.85	

EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 22 of 29

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.) 0 Latency	5 yr	10 yr	15 yr	Comments
111	1975	50 Cavan	.318	33 - 36	3	.85	.81	.81	.81	.81	
		Ellen	.335	36	1	.85	.28	.28	.28	.28	
		17 King	.335	36 - 49	13	.85	3.70	3.70	3.70	3.70	
		11 Park	.229	49 - 66	17	.85	3.31	3.31	3.11	2.14	
		12 Caroline	.229	66 - 72	6	.85	1.17	.78	-	-	
		211-A Walton	.318	72 - 73	1	.85	.27	-	-	-	
		6-31 Mill N.	.318	73 - 75	2	.85	.54	-	-	-	
		TOTAL			43		10.08	8.88	7.90	6.93	
112	1976	Trinity College	.318	33 - 76	43	.85	11.62	10.27	8.92	7.57	
		TOTAL			43		11.62	10.27	8.92	7.57	
113	1972	Hope N.	.318	33 - 34	1	.85	.27	.27	.27	.27	
		*	.229	45 - 47	2	.6	.27	.27	.27	.27	
		Trinity College	.318	47 - 72	25	.85	6.75	5.41	4.05	2.70	
		TOTAL			28		7.29	5.95	4.59	3.24	
114	1976	Telephone	.229	63 - 64	1	.85	.19	.19	-	-	
		277 Ridout	.229	65 - 66	1	.85	.19	.19	-	-	
		3 Toronto	.229	70	1	.85	.19	.19	-	-	
		91 Mill N.	.229	70 - 72	1	.85	.19	-	-	-	
		Barrett Terrace	.229	72	0.5	.85	.10	-	-	-	
		32 Ward	.229	72	0.5	.85	.10	-	-	-	
		80 Dorset E.	.229	73 - 76	3	.85	.58	-	-	-	
		TOTAL			88		1.54	.57	-	-	
115	1975	41 South	.229	60 - 75	15	.85	2.92	1.95	.97	-	
		TOTAL			15		2.92	1.95	.97	-	

* address unknown at time of report preparation, assumed structure exposure value used

EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 23 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.)				Comments
							0 Latency	5 yr	10 yr	15 yr	
116*	1978	159 Cavan	.224	33 - 45	12	.6	1.61	1.61	1.61	1.61	
		159 Cavan	1.147	45 - 60	15	.6	10.32	10.32	10.32	10.32	
		21 John	.229	60 - 51	1	.6	.14	.14	.14	-	
		21 John	.229	62 - 63	1	.6	.14	.14	.14	-	
		132 Walton	.224	64 - 67	3	.6	.40	.40	.40	-	
		132 Walton	.224	67 - 69	2	.85	.38	.38	-	-	
		7 Walton	.224	70 - 73	3	.85	.57	.57	-	-	
		30 John	.224	73 - 77	4	.85	.76	-	-	-	
		88 King	.400	77 - 78	1	.85	.34	-	-	-	
		TOTAL			42		14.66	13.56	12.61	11.93	
116*	1979	159 Cavan	.224	33 - 45	12	.6	1.61	1.61	1.61	1.61	
		159 Cavan	1.147	45 - 60	15	.6	10.32	10.32	10.32	10.32	
		21 John	.229	60 - 61	1	.6	.14	.14	.14	.14	
		21 John	.229	62 - 63	1	.6	.14	.14	.14	-	
		132 Walton	.224	64 - 67	3	.6	.40	.40	.40	-	
		132 Walton	.224	67 - 69	2	.85	.38	.38	.19	-	
		7 Walton	.224	70 - 73	3	.85	.57	.57	-	-	
		30 John	.224	73 - 77	4	.85	.76	.19	-	-	
		88 King	.400	77 - 79	2	.85	.58	-	-	-	
		TOTAL			43		15.00	13.75	12.80	12.07	
116*	1980	159 Cavan	.224	33 - 45	12	.6	1.61	1.61	1.61	1.61	
		159 Cavan	1.147	45 - 60	15	.6	10.32	10.32	10.32	10.32	
		21 John	.229	60 - 61	1	.6	.14	.14	.14	.14	
		21 John	.229	62 - 63	1	.6	.14	.14	.14	.14	
		132 Walton	.224	64 - 67	3	.6	.40	.40	.40	-	
		132 Walton	.224	67 - 69	2	.85	.38	.38	.38	-	
		7 Walton	.224	70 - 73	3	.85	.57	.57	-	-	
		30 John	.224	73 - 77	4	.85	.76	.38	-	-	
		88 King	.400	77 - 80	3	.85	1.02	-	-	-	
		TOTAL			44		15.34	13.94	12.99	12.21	

* final year of exposure uncertain at time of report preparation

EXPOSURE SUMMARY SHEET

Proj. 30063 Sheet 24 of 24

File Number	Exposure to	Residence	Annual W.L.M.	Period 19__ to 19__	# of Years	Occupancy Factor	Exposure (W.L.M.) 0 Latency	5 yr	10 yr	15 yr	Comments
116*	1981	159 Cavan	.224	33 - 45	12	.6	1.61	1.61	1.61	1.61	
		159 Cavan	1.147	45 - 60	15	.6	10.32	10.32	10.32	10.32	
		21 John	.229	60 - 61	1	.6	.14	.14	.14	.14	
		21 John	.229	62 - 63	1	.6	.14	.14	.14	.14	
		132 Walton	.224	64 - 67	3	.6	.40	.40	.40	.13	
		132 Walton	.224	67 - 69	2	.85	.38	.38	.38	-	
		7 Walton	.224	70 - 73	3	.85	.57	.57	.19	-	
		30 John	.224	73 - 77	4	.85	.76	.57	-	-	
		88 King	.400	77 - 81	4	.85	1.36	-	-	-	
		TOTAL			45		15.68	14.13	13.18	12.34	
117	1969	Ott Mansion-King	.229	46 - 49	3	.85	.58	.58	.58	.58	
		Old Hospital Nurse Resid.	.229	50 - 64	14	.85	2.73	2.73	1.75	.78	
		38 John no. 3	.224	64 - 68	4	.6	.54	-	-	-	
		50 Wellington	.318	68 - 69	1	.6	.19	-	-	-	
		TOTAL			22		4.04	3.31	2.33	1.36	

*final year of exposure uncertain at time of report preparation